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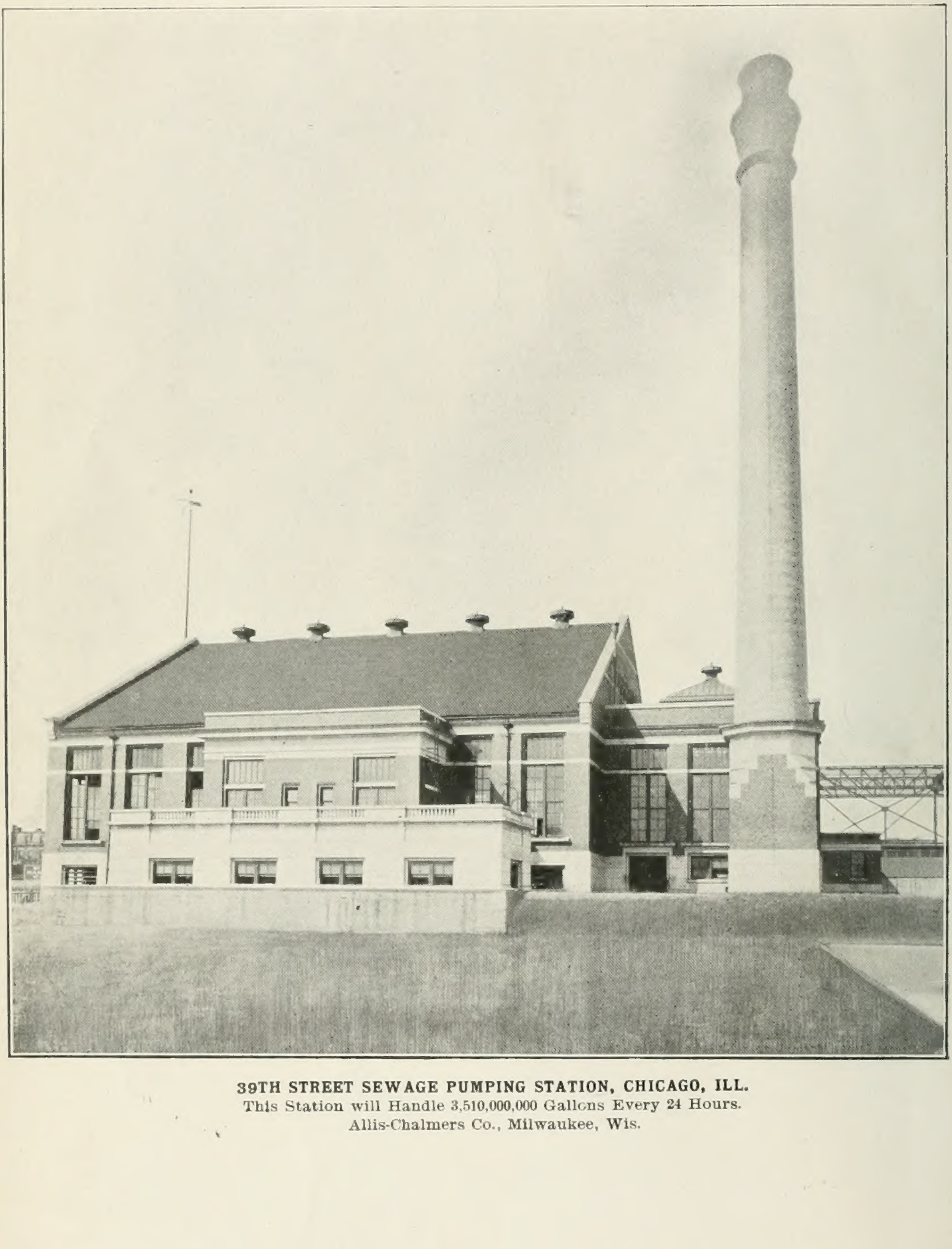

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Engineering Firms and Manufacturers in making these volumes thoroughly representative of the latest and best practice in every branch of the broad field of Heating, Plumbing, and Sanitation; also for the valuable drawings, data, suggestions, criticisms, and other courtesies.

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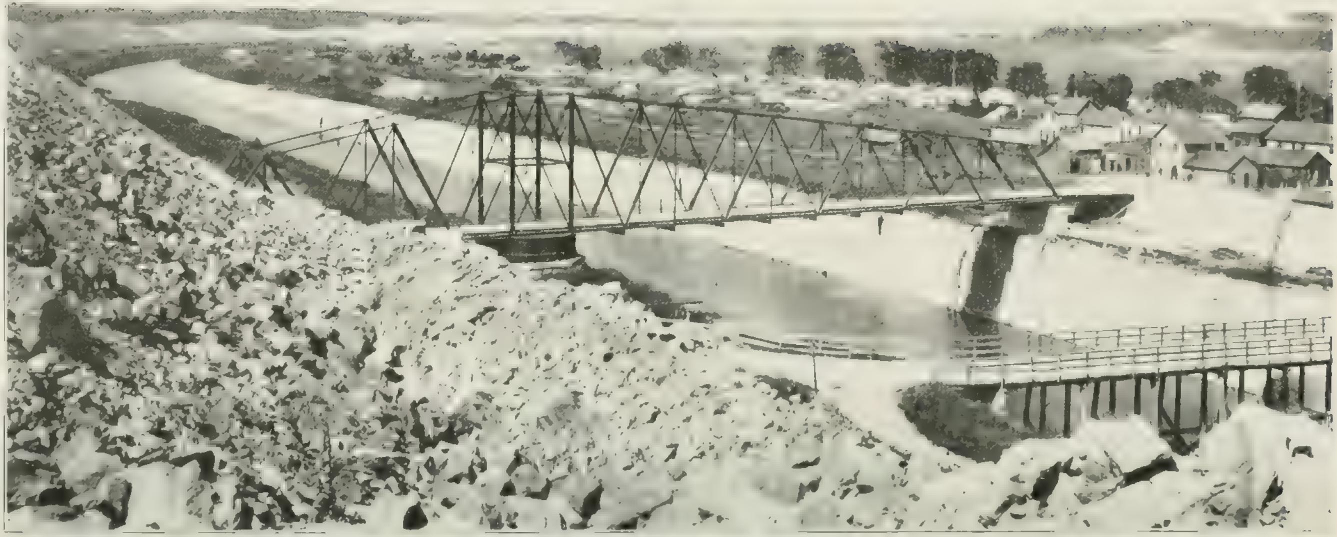


CURVE IN CHICAGO DRAINAGE CANAL NEAR ROMEO, ILLINOIS

The white streak along the bank is all stone excavated from the channel. The limestone taken out in the construction of this waterway, which is practically a 25-mile extension of the harbor of Chicago, has a market value, for concreting, paving, etc., of about $30,000,000.

Foreword

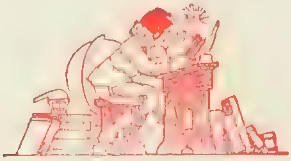
THE widespread need for a more scientific knowledge of the principles of Sanitation on the part of thousands of practical men of limited education, calls for an authoritative work of general reference embodying the results of modern experience and the latest approved practice. The Cyclopedia of Heating, Plumbing, and Sanitation is designed to fill this acknowledged need.

¶ The Cyclopedia of Heating, Plumbing, and Sanitation is based upon the method which the American School of Correspondence has developed and successfully used for many years in teaching the principles and practice of engineering in its different branches. It is a compilation of representative Instruction Books of the School, and forms a simple, practical, concise, and convenient reference work for the shop, the library, the school, and the home.

¶ The success which the American School of Correspondence has attained as a factor in the machinery of modern technical and scientific education, is in itself the best possible guarantee for the present work. Therefore, while these volumes are a marked innovation in technical literature—representing, as they do, the best ideas and methods of a large number of *different* authors, each an acknowledged authority in his work—they are by no means an experiment, but are in fact based on what has proved itself to be the most successful method yet devised for the education of the busy workingman. They have been prepared only after the most careful study of modern needs as developed under the conditions of actual practice.

¶ Neither pains nor expense have been spared to make the present work the most comprehensive and authoritative in its field. The aim has been, not merely to create a work which will appeal to the trained expert, but one that will commend itself also to the beginner and the self-taught, practical man by giving him a working knowledge of the principles and methods, not only of his own particular trade, but of all allied branches of it as well. The various sections have been prepared especially for home study, each written by an acknowledged authority on the subject. The arrangement of matter is such as to carry the student forward by easy stages. Series of review questions are inserted in each volume, enabling the reader to test his knowledge and make it a permanent possession. The illustrations have been selected with unusual care to elucidate the text.

¶ Grateful acknowledgment is due the corps of authors and collaborators—men of wide practical experience, and teachers of well-recognized ability—without whose hearty co-operation this work would have been impossible.



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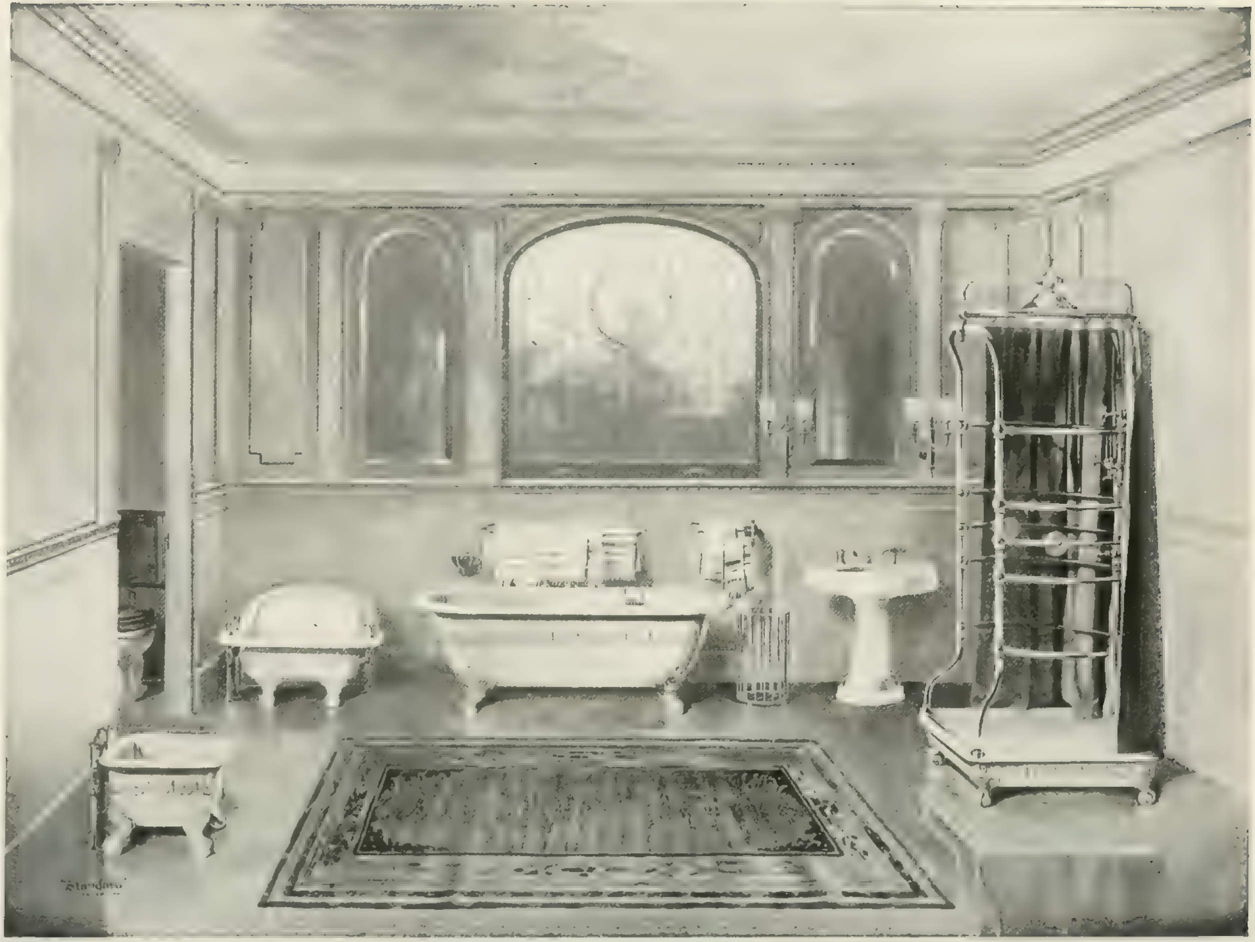

TYPE OF MODERN AMERICAN BATH ROOM WITH LATEST APPROVED FITTINGS.
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PLUMBING

PART I

Plumbing occupies an important position among the trades as an application of Sanitary Science.

Sanitary science is defined by an eminent authority* as "that body of hygienic knowledge, which, having been sufficiently and critically examined, has been found so far as tested to be invariably true. Its phenomena are natural phenomena; its laws are natural laws; its principles are scientific principles."

The same authority defines the sanitary arts as "those methods and processes by which the applications of the principles of sanitary science are effected," and would include plumbing with other practical arts of construction involved in sanitary engineering and architecture.

Having thus noted the position occupied in this broad field by the matters under consideration, we may define plumbing as *the art of placing in buildings the pipes and other apparatus used for introducing the water supply and removing the foul wastes.*

Historically, the plumber is primarily one who works in lead; but this definition would be a misnomer applied to the handicraftsman of to-day. While in time past, and even within the memory and practice of men now working at the trade, it suited the occupation designated as *plumbing*, the term "plumber" survives the transition from lead to iron more by reason of established usage than from its fitness to indicate the workman of the present.

Two score of years ago, traps and soil, waste, and supply pipes were in many localities almost wholly of lead; and much of the larger pipe was hand-made. Lead was then everywhere more frequently used for all these purposes than it is anywhere in the country now. To-day, first-class plumbing is possible in any type of building without employing a vestige of lead, and that, too, with fixtures and fittings regularly on the market. Lead, however, is still used to a marked extent in plumbing, principally for traps, pipe connections, calked joints, water-service pipes, tank linings, flashings, etc. Its retention for these secondary purposes is due generally to superior fitness; yet

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* *The Principles of Sanitary Science*, by Wm. T. Sedgwick.

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in some instances it is because of the style of connection provided on certain fixtures, or for other reasons independent of the merits of the metal. On the whole, its loss of prestige has been slow and impartial. Indeed, those manually skilled in the manipulation of lead have often opposed the adoption of other materials sufficiently to retard substitution of the better.

Lead has unequaled merit for plumbers' use in specific instances; and if the trade has suffered by injudicious substitution of other material during its rapid evolution in recent years, time will adjust the error as the fitness of lead becomes apparent. For service lines in the ground, no other material lasts longer or gives more satisfaction than lead, provided the use of lead is safe with the particular water which flows through it. For cold-water lines inside buildings, it answers well. Wood tanks properly lined with lead are, in many cases, the best for indoor storage.

Lead pipe is not self-supporting in any position, in the sense that iron or brass may be considered so; and the providing of reasonably permanent support for lead work is an expensive item. Lead pipe costs more than iron or brass, in every case; and the cost increases proportionally with the extra weight necessary for all but very light pressures; while ordinary merchant's iron pipe, or seamless brass pipe of iron-pipe size, will withstand the pressure of any municipal or private supply in America.

Lead does not serve well for hot water. The contraction while cooling appears not to equal the expansion from heating; hence the pipe deteriorates at the hottest points, usually showing weakness first near the reservoir in the kitchen, especially at bends, and finally crystallizing beyond repair at those points. So much trouble has been experienced with stove and range connections of lead, that lead pipe for this purpose has been entirely abandoned. The wish to install something better suited than lead for hot-water service, is in large measure responsible for the general adoption of other material. Hot and cold supply lines that are dissimilar in material, in diameter, in joints, and in fastenings, are so unsymmetrical and out of harmony in every way that no mechanic is willing to install them for a slight real or fancied betterment.

With reference to the action of frost, lead pipe has an advantage in that the diametrical expansion of the water when freezing does not burst the pipe at the point frozen, unless it has been repeatedly swelled from the same cause. Lateral extension of the core of ice in the portion frozen, crowds the water which it cannot compress; and, as the ice is frozen to the wall of the pipe, the weakest place ruptures. Sometimes a faucet ball will be driven in, and occasionally a coupling collar will be stripped of its threads; but usually room is made for the extra volume of the water by the pipe swelling to an egg-shape and bursting at one point. Such a break can be repaired by wiping a single patch or joint on the original pipe.

Frost breaks in lead pipe nearly always occur on the house side of the point frozen, because the water in the street end is easily driven toward the main. Air-chambers on the house service would often obviate the bursting of lead pipe; but where the type of faucets or a limited pressure does not require their use in order to prevent reaction, plumbers frequently omit them, under the impression that air-chambers can serve no other good purpose.

With iron pipe, frost breaks are more serious. Diametrical expansion splits the pipe at the point frozen every time freezing occurs; and lateral extension of the ice staves in the faucet stems, etc., quite as frequently as would happen with lead pipe under the same conditions. Of late years, the improvement in types of buildings, more careful provision against frost on the part of plumbers, and the vigilance of the Weather Bureau in giving warning of approaching cold snaps, have made insignificant the amount of damage by frost in both kinds of pipe.

Lead pipe, as a rule, requires less trench work on ground lines than iron pipe, because drilling, even if very poorly aligned, will often suffice to get the pipe in place. There are numerous instances, however, where longer stretches of iron pipe have been placed in drilled holes than would be practicable with lead at the same excavating cost. It is well to remember that any small line of house service in the ground should be placed deeper, so far as immunity from frost alone is concerned, than is necessary for the protection of large pipes in the same locality, because the volume of contents in house pipes is small, the wall surface of the pipe relatively large, and the flow of the water not so regularly maintained.

The action of natural waters on lead has been a matter of wide discussion by able men. The subject of possible contamination of water supply through the agency of lead conduits, is too broad, however, for full consideration here, and will therefore be but briefly touched upon. This trait of lead has been voiced against its use, with more or less effect; but known cases of poisoning from this source have been exceedingly rare. Galvanized-iron pipe charges the water with salts of zinc when the water contains certain impurities; and most other kinds of pipe are also more or less open to objection at times by reason of their injurious effect on the water, the staining of fixtures, etc. Some of the salts of lead formed by the agency of water conveyed through lead supply pipe, are protective. Others, without doubt—fortunately of rare occurrence is actual practice—are corrosive. Sulphate or phosphate of lime, in solution, will part with its acid in passing through lead pipe, the acid combining with a new base (lead) and forming sulphate or phosphate of lead as the case may be. Chloride, sulphate, nitrate, borate, and other compounds of lead, may be similarly formed. These incrust the pipe; and such of them as are practically insoluble in water protect the lead from further attack, thus preserving the quality of the water. Carbonate, sulphate, and phosphate of lead, which doubtless form most frequently in lead water pipes, belong to the protective class. Of course, not all the compounds mentioned are encountered in any one source of supply. Chemical compounds designed to produce an insoluble incrustation have sometimes been purposely placed in solution, and allowed to stand in systems of lead supply pipe where it was known that the water to be commonly used would otherwise be dangerously corrosive. In view of the possibility of such precautionary measures, the deleterious effect of lead on many water supplies, and the consequent menace to health if lead were used indiscriminately, could hardly alone to any appreciable extent result in the substitution of pipe of other material.

Lead has been thus dwelt upon at the outset, because the industry of plumbing itself derived its name from this metal (*Plumbum*, Latin for "lead"). A discussion sufficient to define broadly the present and past status of the metal in the plumbing business, is certainly apropos in this connection. To many persons, the term "Plumbing" suggests lead and lead work generally, without regard to its distinctive forms, some of which are quite foreign to the ordinary trade meaning. To those acquainted with the building practices of Europe, visions of lead-covered roofs and spires, rainwater heads, etc., in addition to manifold other uses of the metal not common in America, may come to view in the mind's eye when "plumbing" is mentioned. To American plumbers of the past generation, "plumbing" suggested stacks of hand-made lead soil and waste pipe; hand-made lead traps; lead "safe" pans cumbersomely boxed-in under fixtures; ridiculously small lead ventilation pipes; lead drip-trays; lead supply pipes (sometimes also hand-made); all "wiped" joints and seams; and blocks, flanges, braces, boards, and boxes galore, jutting out in profusion, for supports, covering, etc.

In reality, we in America have now but little of what the name "plumbing" would lead the uninitiated to expect. Stacks of plain or galvanized wrought-iron pipe, or of plain, tarred, or galvanized cast-iron pipe, of weight to suit the height of building and to serve as main soil, waste, and ventilation pipes, with sundry lead bends and ends for fixture connections—these, with galvanized wrought-iron or brass pipes for supply, constitute the "roughing-in" stage of a job of plumbing; while painted or bronzed main lines exposed to view, galvanized-iron and nickel-plated brass pipe, with fixtures, partitions, etc., make up a view of the finished work, conveying little idea of the functions and importance of the unseen portions. Finished work in an unpretentious dwelling or storehouse, when properly charted, is fairly easy for even the house-man to understand. In large apartment and office buildings, department stores, etc., however, the plumbing, ventilating, gasfitting, heating, and automatic sprinkler pipes and electric conduits, make, in any but the finished state, a maze of pipe beyond the understanding of any except engineers well versed in those lines of work. In the completed work, the details are concealed. The toilet rooms present an orderly perspective of closets, lavatories, or other fixtures, as the case may be, with simple connections according with the customary finish, kind, or purpose of the pipe.

This apparent harmony, proportion, and simplicity in the result, coupled with a memory of sundry glimpses of a confusion of pipes in the rough state, has, it is to be regretted, propagated in many minds, a sense of false security regarding plumbing, based on the assumption of the plumber's evident ability to produce order and perfect service out of what in the "roughing-in" stage looked chaotic to a hopeless degree. The bulk of plumbing work, however, is not of the "skyscraper" class, nor is it handled by the same type of skill and superintendence. Any feeling of confidence or sense of security on the part of the public, is treacherous if based on the assumption that only by a degree of skill in direct proportion to the size of the job can satisfactory plumbing service be provided in residential and other small buildings. There is evidence of a somewhat indifferent state of the public mind regarding the plumber and his work, induced by the reasons stated and also by lack of due consideration and appreciation of conditions wrought by progress in other trades.

Plumbing, in its advancement, is merely keeping pace with the allied lines on which it is dependent. Their progress has created new conditions to be met; and as the future plumber will hail from the ranks of the populace, the light in which the public regards the plumber and the importance of his trade will have no uncertain bearing on the character and earnestness of those who take up the calling. The rank and file of apprentices have already too long been attracted merely on the score of a promising means of livelihood. There is ample reason to begin a plumbing career with all the pride felt by followers of any other vocation. It is altogether improbable that any individual will be found with so much education or such promising ability as to give rise to just grounds of fear that plumbing will not offer him sufficient scope to acquit himself with dignity.

The advent of tall buildings, the general increase in the height and other proportions of buildings in cities, and the changes in material and in design of fixtures, together with the abnormal demand resulting from the decreased cost, natural growth, and gradual awakening through education to the value of sanitary conveniences, have brought about a condition of affairs which the old-line plumbers were incapable of coping with, and which the old apprenticeship system was inadequate to provide men capable of dealing with in a creditable manner. The plumbing of one large building involves as much work as hundreds of the average small jobs put together. The handling of such work under the conditions that have prevailed, has developed a deplorable state of so-called "specialism." Men engaged in "roughing-in" a large job are likely to tell you with entire truthfulness that they have no idea what types of closets or other fixtures are to be used; that they know nothing of the principles or merits of plumbing fixtures, and do not need to; that they never connected a fixture in their whole career; that the finishers do that kind of work. By further inquiry one would find the "finishers" utterly at sea in the work of "roughing-in," and accordingly ignorant of the whys and wherefores that govern the success of a job as a unit. These men, called "plumbers," are exceedingly skilful and rapid within their limitations; but it is easy to infer the fate of a job intrusted to such hands alone, and in practice it has been proven that others of metropolitan practice, and merely lacking in variety of experience, were not capable of creditable results on general residence work of the ordinary class.

When the largest jobs were completed in a comparatively short time, and when much of the training which went to make up the plumber's accomplishments was credited to the manual practice necessary to master the working of lead and solder, a period of service in shop and job practice, coupled with oral instructions from the journeyman, served fairly well to make a plumber out of raw material within the period allotted by the American abridgment of the apprenticeship term. On the work of to-day, however, there would be great chances of an apprentice serving such a term without seeing anything of more than from two to five jobs. He would be lucky if it fell to his lot to get even a little experience in each of the natural divisions of those jobs; and again fortunate if those jobs happened not to have the same general layout or to employ identically the same make of fixtures, for there are many shops which seem to have the faculty of securing work from certain particular sources, and which are equally likely for one reason or another to be recommending and using, where possible, one particular make of goods to the exclusion of other kinds just as good or better. These and kindred features now met with on every hand in practice, are stumbling-blocks—prohibitive, in fact, of anyone learning the plumbing trade within any period of time that can sensibly be prescribed for the acquiring of a trade or profession.

For more than a decade, the often-avowed reluctance of journeymen to teach apprentices has been held responsible for the trend of these affairs affecting the practice of the industry; but in the light of what has been said, it is easy to determine what it was that really introduced the Plumbing Correspondence School and Plumbing Trade Classes. It was *necessity*. Trade journals have done and are still doing good work in this line; but their best efforts, added to the opportunities of practice, were insufficient. There was no other satisfactory solution than the Correspondence School—no other route to the acquisition of principles and acquaintanceship with the accumulated information as to the relative merit or fitness of certain materials, designs, systems, etc., and as to the conditions under which this or that would serve well, while it might act just the reverse under other circumstances.

Under the present *régime,* it is not only apprentices and those who intend becoming such, but journeymen as well, that need to seek aid in the schools. The citizen at large, also, serves his own interest in informing himself in a general way at the same fountain, so as to be able to discriminate for himself in matters pertaining to plumbing. Furthermore, any real plumber would prefer that his customer should be familiar with the work in hand. Fewer misunderstandings occur when such is the case, and there is a keener appreciation of good work on one hand and a corresponding effort to merit approval on the other. There is, too, in favor of the plumber, when the customer is informed, an absence of those niggardly tactics of trying to secure much for little, of sacrificing quality and future satisfaction by reducing first cost below the safe limit. The well-informed customer never makes you feel that all plumbing is alike to him and a necessary evil to be paid for at rates far in excess of its value.

With the foregoing introduction in mind let us look further into the subject and see what "Plumbing" really is. Whether we are actual or self-nominated apprentices, journeymen, masters, or the prospective customer himself, a view of the matter will be beneficial, if only in the sense of refreshing memory.

There was a time when sanitary conveniences, crude in comparison with the present, were considered mere luxuries. Under the present views of life and the conditions of living, we may with greater propriety consider these erstwhile luxuries as actual necessities, though they are often luxurious to a degree that dwarfs into insignificance other appointments which even then were granted to be essentials. Plumbing is, therefore, neither in fact nor in opinion, a matter of simple luxury for the rich and delicate, but is, rather, an important subject of deep salutary interest on the one hand and of business acumen on the other—a matter of essentials deeply affecting the best interests of our own health and that of our neighbors, with which mere sentiment has no ground for association. The time when it was thought sufficient to fan out the mosquitoes in summer and break the ice in winter at the family rain barrel in order to wash our faces and hands, has passed. A dwelling job may now embrace almost the entire range of plumbing fixtures. There is therefore no better example from which to build a word-picture of Plumbing.

PLUMBING FIXTURES

Bathtubs. Bathtubs are a prime factor in plumbing. They are of various types: (1) Wooden cases, with sheet-metal lining, usually copper, on the order shown in Fig. 1; (2) all copper, and steel-clad, suitably mounted, as shown in Fig. 2; (3) cast iron, enameled, with a vitreous glaze fused on the iron, as in Figs. 4 and 5; (4) solid porcelain, potter's clay properly fired, with vitreous glaze fired on, as in Fig. 3; and (5) marble, variegated or otherwise, cut from the solid block. Their cost ranges in the order mentioned.

The relative merit of the different materials and types is not so easily designated. Porcelain and marble baths are large, very heavy, and imposing-looking; and therefore are often selected on the score of massiveness, with a view to harmonizing with the dimensions and finish of the house. One would suppose the mass of material in such baths would have the effect of cooling the water to an annoying extent; but careful tests have revealed no appreciable difference in the effect of thin as compared with thick bathtubs on the warmth of water, and but little in their pleasantness of touch to the person. The bath of most pleasant touch was that of indurated wood fiber, which, however, had but little commercial success, on account of its lack of stability.

Most baths are made in from two to five regular sizes, ranging from 4 to 6 feet in extreme length. The general shapes are the *French* (Fig. 3); the *Modified French* (Fig. 4); and the *Roman* (Fig. 5). The various French patterns have the waste and supply fittings at the foot, which is modified in form to accommodate them. The waste water travels the length of the tub to reach the outlet, and generally leaves scum and sediment on the interior while emptying. Baths of the French type are suited to corner positions, or to positions in which one side runs along the wall; but the ideal position for a bathtub, in the interest of cleanliness, is with the foot end to the wall,

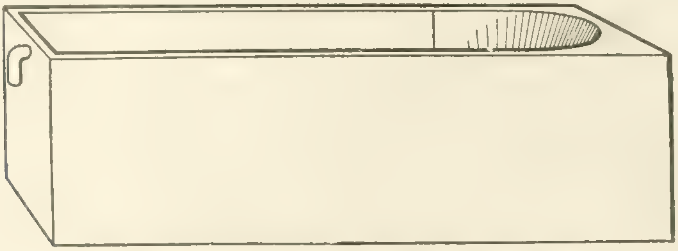


Fig. 1. Wooden Case Bathtub, with Sheet-Metal Lining.

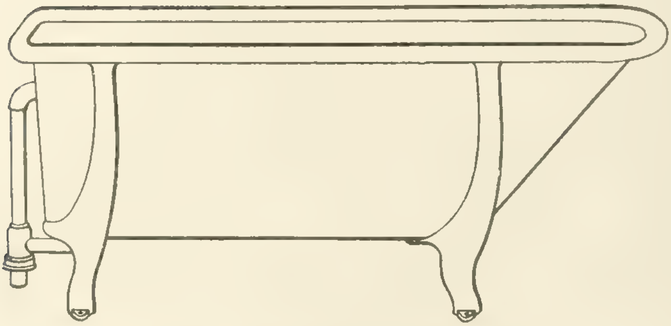


Fig. 2. All Copper, Steel-Clad Bathtub.

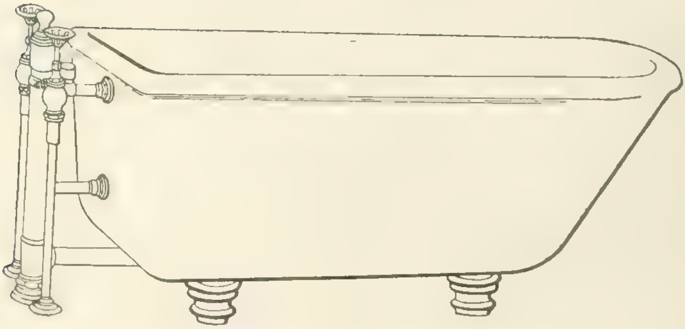


Fig. 3. Solid Porcelain Bathtub, French Type.

thus permitting entrance from either side. A medium size is best suited to the usual provision for supplying hot water for bath purposes; and is also preferred by many because the feet reach the foot, enabling a person, when submerging the body, to keep his head out of water, with his shoulder resting on the slant at the head of the tub. Where the house supply is pumped by hand, the medium size of any kind of bath is advisable.

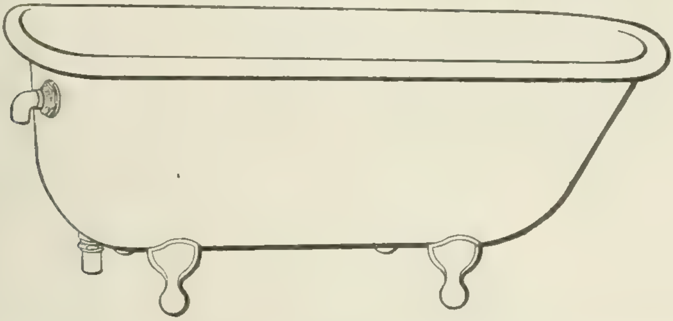


Fig. 4. Enameled Cast-Iron Bathtub, Modified French Type.

The rims of baths vary from 1½ to 5 inches in width. The larger rims are easy on the person in getting in and out of the bath, and are often used in lieu of a bath seat. In iron baths with rims large enough, the fittings are generally passed through the rim, as illustrated in Fig. 6, thus giving them additional stability and making the stated fixture length include the whole space necessary for its installation. This style of bath fitting is shown in Fig. 7.

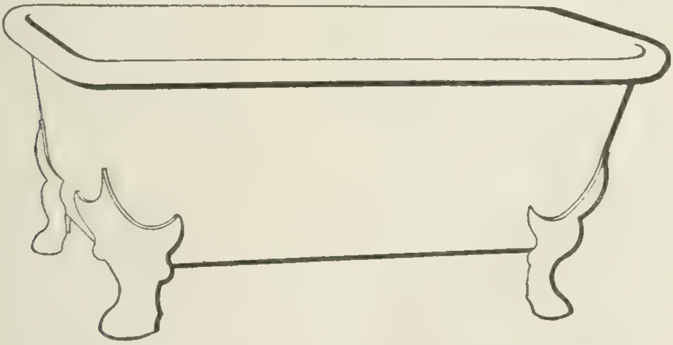


Fig. 5. Enameled Cast-Iron Bathtub, Roman Type.

Nominal sizes of baths now include the whole length of the fixture proper. Formerly many awkward mistakes resulted from lack of uniformity, one not always knowing whether to consider the nominal size as inside measurement only or including twice the rim width. In cast tubs, actual measures vary slightly from the nominal, because of the furnace effect when heating to enamel. The variation, however, is not sufficient to be considered in noting the space required, or to require any advance in roughing-in measurements.

Roman baths have ends alike, with the fittings at the center of one side, as illustrated in Fig. 8, and the waste outlet at the center of width and length. In general, they empty with better effect, and may be placed in either right or left corner or free of all the walls; but the best position, everything considered, is with the fitting side near the wall, and not against either end of the room.

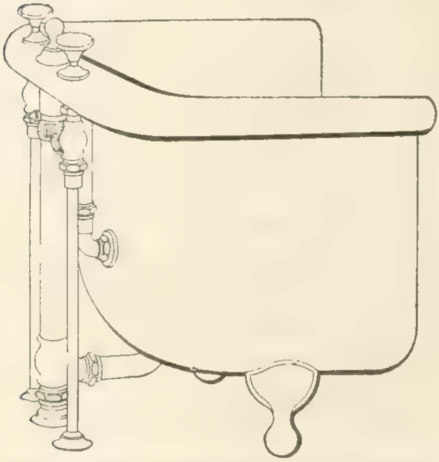


Fig 6 Fittings Passed through Rim of Enameled-Iron Bathtub, to Give Additional Stability.

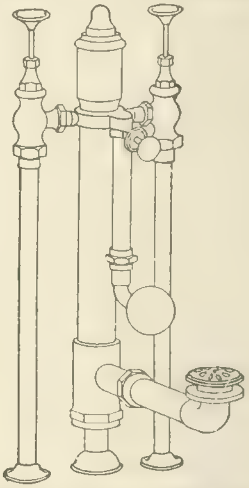


Fig. 7. Style of Bath Fitting Intended to Pass through Rim of Tub.

Any finish for iron bathtubs, other than plain paint, should be put on at the factory; iron surfaces cannot be ground and the successive coats of paint dried on in place, properly or cheaply.

Waste fittings and the outlets of baths have always been made too small. Slow emptying takes valuable time, and results in the adherence of scum, which necessitates careful cleansing of the bath before it is used again.

The fittings of baths are not interchangeable unless the obliqueness of the tub walls and the depth and drilling agree. The styles of fittings are universally applicable, except that double bath-cocks

(Fig. 9) are never placed on Roman baths. All double cocks are provided with detachable coupling and sprinkler, which, fitted to hose, provide a means of spraying the body. Independent spray, needle, shampoo, and overhead shower fixtures, simple and in combination, with or without curtains, are made for use with the various tubs, the tub serving as a receptor for the falling water.

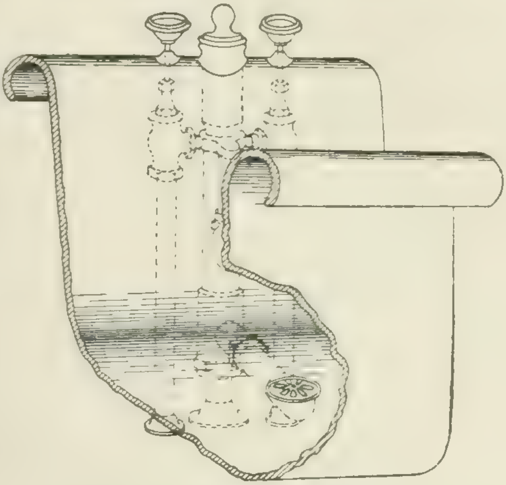


Fig. 8. Showing Central Location of Fittings and Waste Outlet in Roman Bathtub.

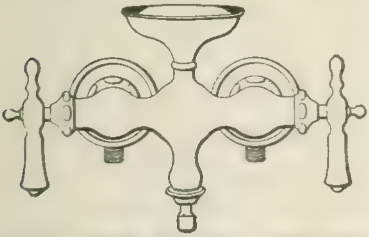


Fig. 9. Double Bath Cock Never Used on Roman Bathtubs.

The cheapest serviceable bath fittings are a Double Cock and Connected Waste and Overflow. These are shown in Fig. 10. Bell Supply and Waste fittings, a special type of which is shown in Fig. 11, are singularly popular, the water being retained by a ring valve attached at the bottom of the overflow pipe, and operated by means of a knob projecting above and through the top of the waste standpipe. This takes the place of the ordinary plug and chain used with the simple overflow. The supplies are made and fitted in combination with the waste arrangement, with the valve handles projecting above the rim of the bath, the two supplies being delivered into a common yoke-piece, where they mix and flow through a common passage to the bell-piece fitted through the vertical wall near the bottom of the bath. With the usual slotted-bell delivery, these fittings are a nuisance in one respect. Water cannot be drawn into a vessel through the bell for any ulterior purpose; and as no vessel of considerable capacity can be filled at the lavatory faucets, or at a sitz or a foot bath, the sink faucets are the only resort unless a slop sink is available. Nozzle-delivery bells, which afford some relief in this respect, are made; and hand sprays used in conjunction with them avoid the expense of special shower fixtures, which would otherwise be essential if shower or spray were desired at all.

A modification of these fittings, termed "Top-Nozzle Supply and Waste" (Fig. 12), overcomes this objection to the strictly "Bell Supply" type. It has a high nozzle delivery projecting into the tub, and is fitted for spray attachment. The inward projection is much less than with a double cock, which, in a short bathtub, would occupy much needed space. The noise of falling water, obviated with the bell placed low, is the same as with the double cock; and the mixing space, intermediate between that of a cock and the regular bell delivery.

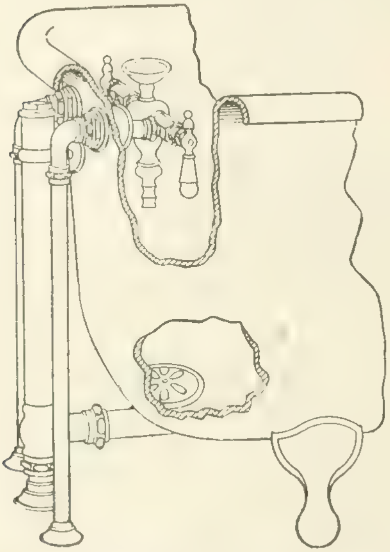


Fig. 10. Common Type of Double Cock and Connected Waste and Overflow.

An element of danger is inherent in a bell-supply outlet placed so low down as to be submerged when the tub is in use. If the supply is opened when the tub contains dirty water, and the pressure of water is lowered by accident or by opening faucets elsewhere, it is quite possible that the fouled water will be drawn back through the bell or nozzle into the supply pipes, thus, perhaps, contaminating the water for domestic use. For this reason, cocks which discharge near the top edge of the fixture, above the level of the water, are increasingly used at present.

For private use, where both children and adults are to be regularly served, the bathtub is the only fixture answering the requirements. As the physical conditions of the members of the family are, or should be, mutually known, and the tub will be regularly cleansed between baths, any possible chance of communicating humors of the skin through the bath can be guarded against. For institutions and general public use, the tub bath is open to serious objections, some of which apply as well to private use. The water for a tub bath is at its best when first drawn into the tub; and the person, before bathing, is certainly in condition to pollute it more or less. As the bathing process nears completion, these conditions are exactly reversed. Tubs used by the public may not be carefully cleansed between times of use, and the bather is ignorant of the condition both of the tub and of the person who used it previously. In institutions for the insane and feeble-minded, unscrupulous attendants have been known to bathe several persons in the same water. Large pools are better, but still not ideal; nor are they always suitable or practicable.

Shower Baths. Shower or rain baths are commonly installed in barracks, gymnasiums, and schools, and are no longer unusual in private dwellings. Some of the objections to the tub bath, which have been stated, are entirely avoided by the shower fixture with its supply of running water. Those who have studied the hygienic effects produced by the action of jets or streams on the surface of the body, urge very strongly that the impact results in stimulating the proper action of the skin. This is the opinion of most persons who have had experience with such apparatus.

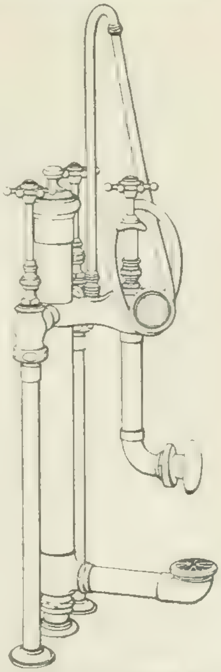


Fig. 11. Bell Supply and Waste Fittings.

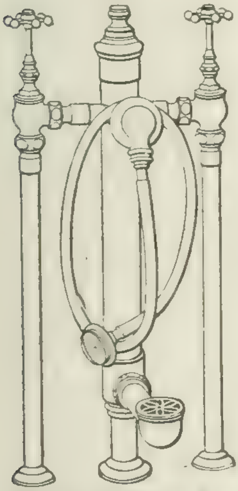


Fig. 12. Top-Nozzle Supply and Waste Fittings

The older forms of showers, which direct the water vertically upon the head of the bather, are not so desirable as those in which the outlet is inclined and placed at about the level of the shoulders, thus avoiding wetting the head unless desired. Indeed, all the essentials of a bath of this form are met by a water-supplied rubber tube discharging at about the level of the waist over a tight floor or pan provided with a drain.

Aside from the shower baths that may be provided in conjunction with a bathtub, one type of which is shown in Fig. 13, many designs are fitted to floor-pans, called *receptors*, usually having a curtain, as in Fig. 14, thus providing for private installations a great variety of complete showering and spraying appointments. The receptors may be enameled iron, porcelain, or marble. A cement or asphalt floor, sloping to a drain, is simple and effective.

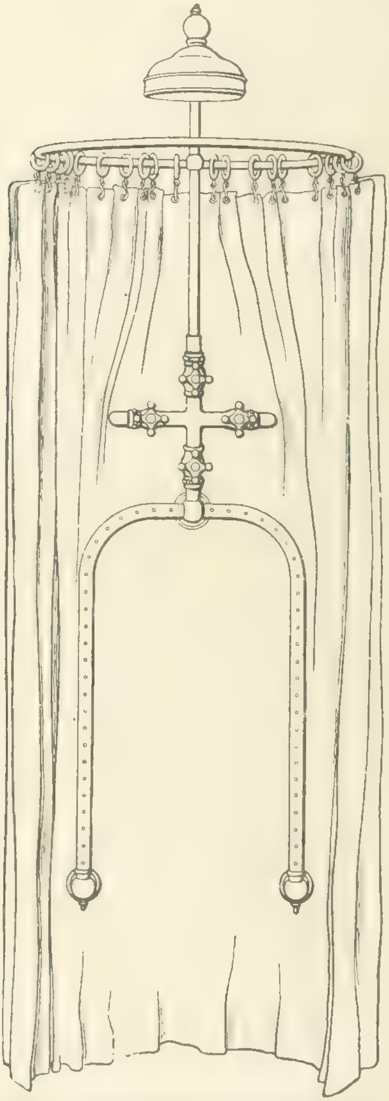
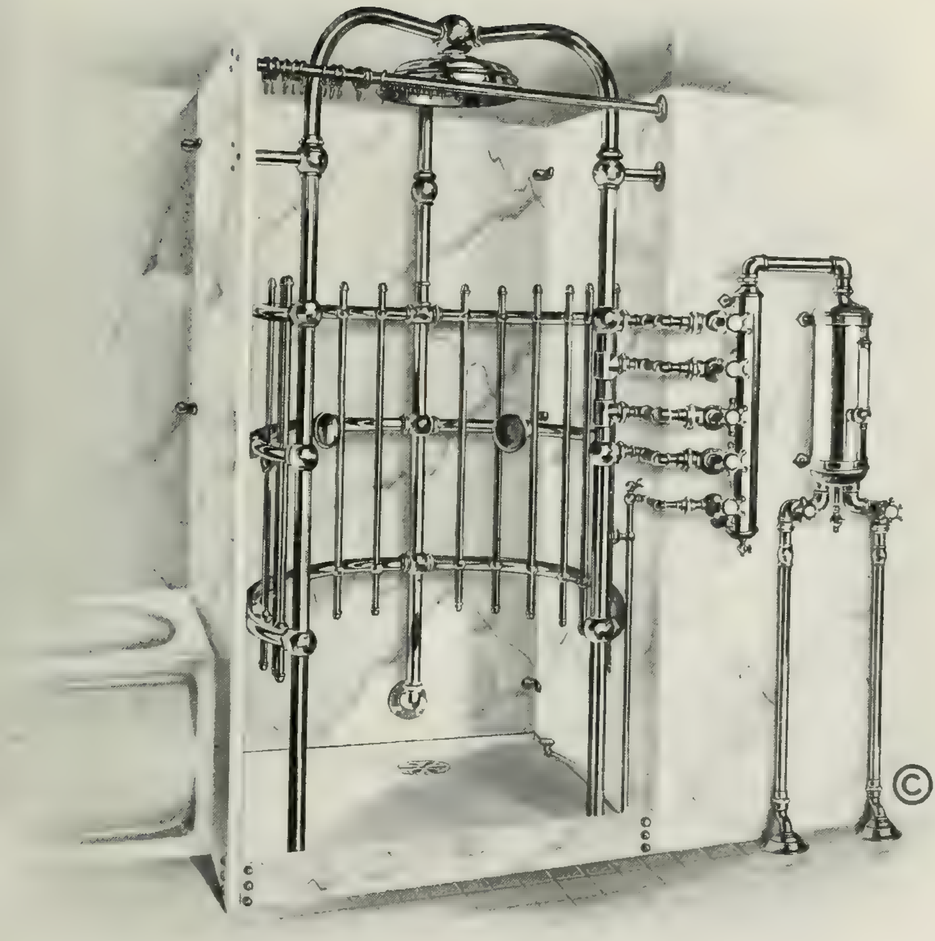


Fig. 13. Type of Shower Bath Provided in Conjunction with Bathtub.

In lieu of the full curtain and regular receptor capable of providing six to eight inches' depth of water, and having tub-like supply and waste fittings in addition to the shower features, a shallow base of marble provided with a drain and having three marble sides, such as is shown in Fig. 15, can be provided with any preferred type of shower fittings. The overhead douche, already noted, set at an angle, with flexible joint for adjustment, as seen in Fig. 16, so that the body can be played on without wetting the hair, is not often fitted to private shower fixtures, as it requires considerable additional space. A rubber cap for the head enables one to use the vertical shower with a fair degree of satisfaction.

A point concerning shower fixtures and relating to the safety of the user, to which special attention should always be given, is that of the valve arrangement. If the design renders it at all possible, as sometimes is the case, one is apt inadvertently to scald himself by at first



COMBINATION SHOWER BATH
This Provides Tubular Rain Shower, Douche, Needle and Liver Spray, Bath and Bidet
Notice Distributing Header and Mixing Chamber
James B. Clow & Sons, Chicago

turning on hot water alone. The chances of injury in this way increase with elaborate combinations, if not carefully guarded against by the designers; and we should not take it for granted that they have provided such safeguards. As a rule, reliable makers do embody ample mixing chambers, thermometers, etc., in such apparatus, where necessary, and they regulate the control of hot-service valves, or in some other way render the improper use of them unlikely.

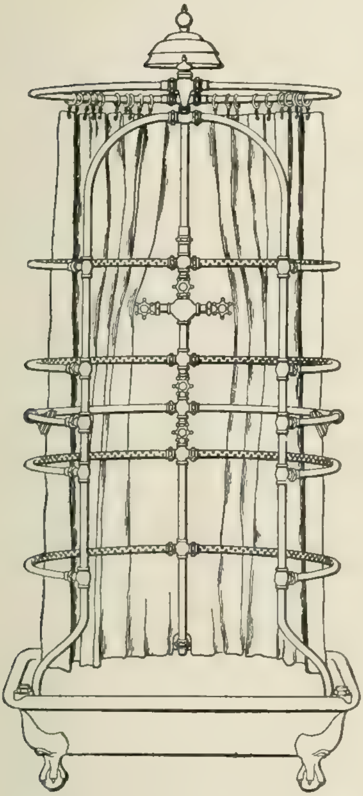


Fig. 14. Shower-Bath, with Curtain Fitted to Receptor.

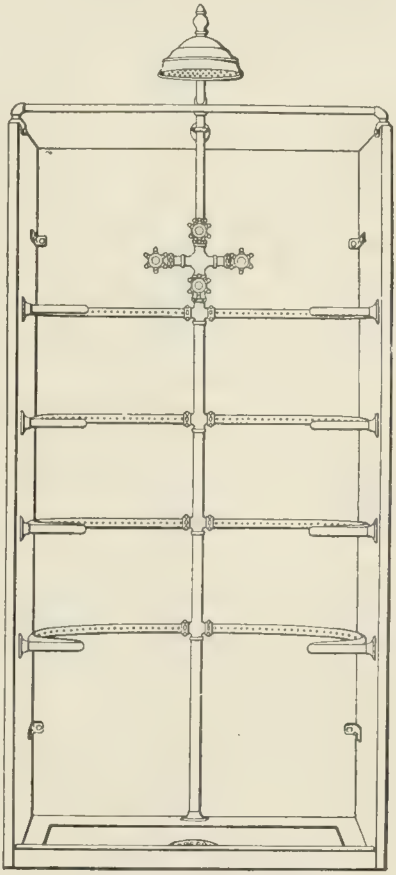


Fig. 15. Shower Bath with Three Marble Sides and Shallow Marble Base.

Sitz Baths. These are primarily for bathing the hips and loins in a sitting posture, but may be fitted with special features as ordered. Porcelain and enameled iron are the usual materials. The fixtures approximate in dimensions 15 inches in height at front and 26 inches at back, and are 26 to 30 inches wide. In the back, at a proper height, in a complete fixture, like that shown in Fig. 17, is a horizontal slit accommodating fittings for a "Liver Spray"—a wide wave-like spray of water, either hot, cold, or of intermediate temperature, as suits the person. In the bottom, in conjunction with the outlet, is a hot or cold douche, equally under control of the user. In the center of the douche, and operated independently, is a Bidet jet. These provisions are entirely separate from and independent of the regular supply fittings, but one waste fitting is used in common for all. The simple sitz bath has the regular Bell Supply and Waste, like those used on the bath, the dimensions being diminished to suit. For the extraordinary features, these fittings are merely adapted in a way to give the user convenient control. For all but the simplest fixtures, the control appliances are invariably fitted through the rims, the valve handles being provided with proper indices to guide the user. Bidet jets in combination with sitz-bath fittings, have to a great extent curtailed the use of separate Bidet fixtures. Bidet jets have often been added to a water-closet, but a satisfactory application cannot be made to a closet. Separate Bidet fixtures are now rare, but are furnished by

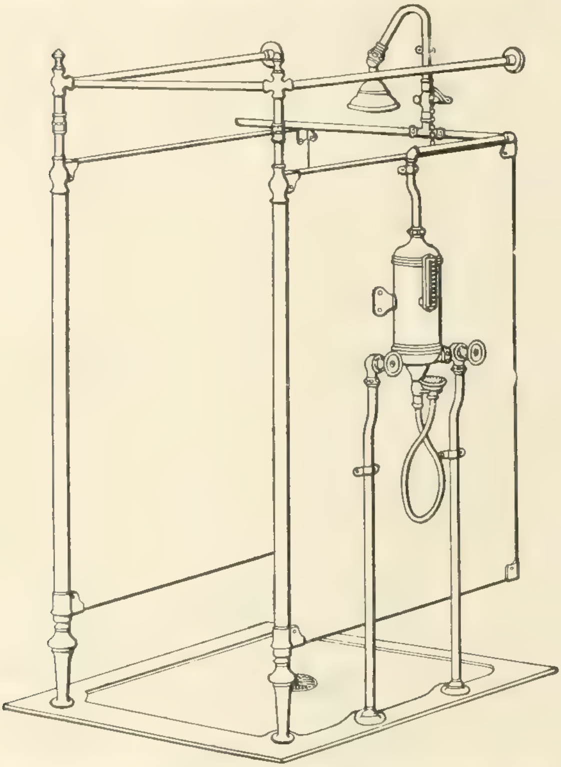
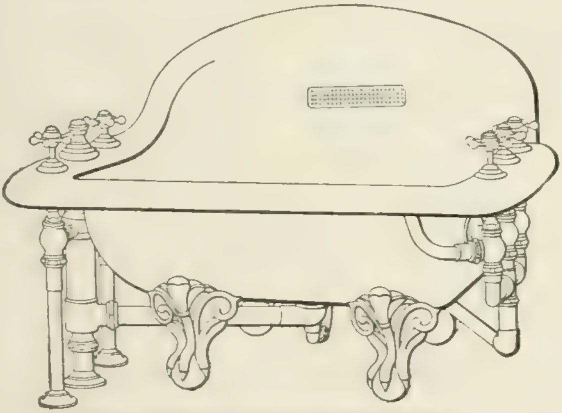


Fig. 16. Shower Bath Fittings with Overhead Douche Set at an Angle on a Flexible Joint.

fixture makers; and in isolated cases, where frequent or regular use is necessary, are preferable to any combination with a fixture used for other purposes.

The sitz bath is conveniently used for a foot-bath, thus making this fixture doubly useful. Indeed, the sitz bath is a more comfortable means of bathing the feet than is the foot-bath itself. Children's bath-tubs, small, and elevated by legs to the height of a lavatory, are made, but no well-defined demand exists for them. Greater convenience to the nurse, the use of less water, and quicker filling and emptying, are the only points in their favor.


No. 17. Sitz Bath, with Complete Fittings.

Foot-Baths. The foot-bath is a small rectangular tub with proper feet and rim, furnished with supply and waste of the regular bath pattern, diminished to suit. The sizes average say 12 inches deep, with 20-inch sides. The feet make the total height about 18 inches. Fig. 18 gives a good idea of the usual enameled-iron foot-bath fixture. Enameled iron and porcelain are the usual materials. They require even less water than the sitz bath, but, as before said, are not so convenient for the purpose as the sitz fixture, and are not installed except in the most spacious and elaborate bath-rooms. The foot-bath would serve admirably as a child's bath, except that it is too near the floor.

Bidet Fixtures. The majority of leading fixture makers do not now catalogue these. They consist essentially of a pedestal like a closet pedestal, with bowl and rim contracted in the center, giving an outline something like the figure 8. Proper fittings to operate the jet and waste are provided. Porcelain is the material. As mentioned before, Bidet jets are furnished in combination with receptor shower fixtures, as well as with sitz baths.

Drinking Fountains. Drinking fountains are now frequently used in stores, schools, and residences, the various fixtures adapted to such installations being readily obtainable. The basins or drip-slabs for public indoor fountains, are often cut to order by the manufacturer; and the cooling and faucet arrangements are provided by the plumber. Porcelain, enameled-iron, and marble fountains of stock designs are made. For schools, trough-like basins, either with open spouts for continuous streams, or with self-closing faucets, as shown in Fig. 19, are frequent. The fixture shown in Fig. 20, consisting of solid porcelain, in which the recessed drain-slab and the high back constitute a single piece, is of recent design, presents an excellent appearance, and has the advantage of being easily kept in immaculate condition. The three deep waste outlets, above each of which is a faucet, afford facilities to many users in a short space of time.

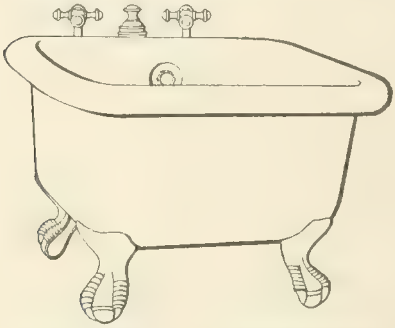


Fig. 18. Common Type of Enameled-Iron Foot Bath.

One device which serves well for common use, is the ordinary lavatory, provided with a stiff perforated bottom fitting extending well up toward the top of the bowl. This, with a proper faucet on the slab, and a cup-chain fitted to the extra faucet-hole, makes a useful but not attractive fixture.

Recessed porcelain and enameled fountains designed to be placed in wall niches, and having concealed connections, as suggested by Fig. 21, are neat, and require very little room outside the finished wall line. Countersunk slabs with strainer waste, with back either integral or separate, as design or material dictates, are made in marble and porcelain. Marble fountains are adaptable to any location, because the slab and back can be cut to any shape or dimensions preferred. The fountain proper, faucet, cup, and pipe waste connection, with strainer, are all that is supplied by the makers.

A type of fountain shown in Fig. 22, is provided with a flowing jet of water from which one can drink without placing the lips in contact with any metal surface. The small central bowl or cup is constantly submerged and cleansed in the stream of water which passes outwardly over it, thus avoiding the danger incident to the common use of the same drinking cup by many persons. The surface does not afford lodgment to possible germs of disease, which are most liable to transmit contagion when allowed to become dry and adhere to a surface.

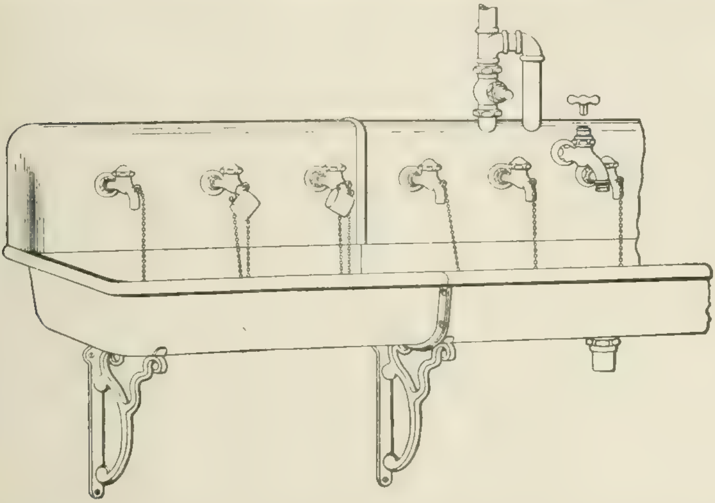


Fig. 19. School Drinking Fountain—Enameled Iron, with Self-Closing Faucet.

Lavatories. Lavatories are made from porcelain, enameled iron, marble, and onyx, in numerous patterns. The number of designs is so large that they are best understood if considered in the classes into which they may be divided. In marble and onyx fixtures, the slab, back, and bowl are necessarily separate pieces. In any but very accurate fitting and erecting, the unavoidable joints soon, if not from the beginning, invite the accumulation of dirt. Poor workmanship, settling, abortive countersinks, and

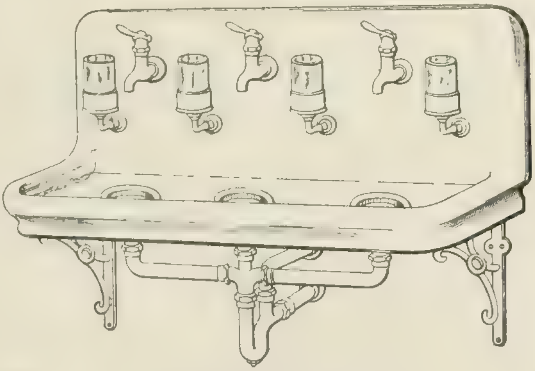


Fig. 20. Porcelain Drinking Fountain, Recessed Drain-Slab and High Back in One Piece.

faucet bosses not cut free within the countersink, have in many cases brought slab types of basins into unjust repute, or, at least, have given basis for strong talking points against them, which have been effectively so used. If made and installed in the most approved manner, these styles, properly cared for, offer little reason for severe criticism. One fact, however, must be borne in mind when comparing marble with other materials used for plumbing fixtures—namely, that marble is *not an impermeable stone.* Nearly all marbles (excepting only the very hardest and most dense) are quite absorbent, and depend upon the surface finish given to the

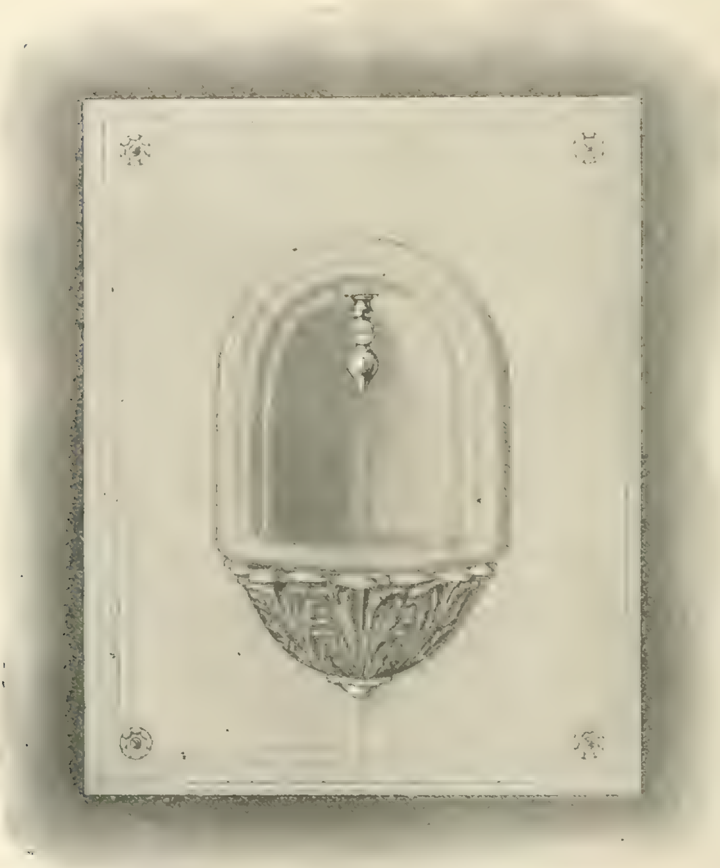


Fig. 21. Porcelain Recessed Drinking Fountain.

slab to resist the entrance of liquids into the body of the stone. As soon as the surface becomes roughened by wear, the greasy and acid wastes penetrate into the pores, and the marble becomes permanently discolored. Only a limited observation of the bad condition of marble floors or urinal slabs which have been subjected to use for a few years, is necessary to confirm this statement.

Ordinary Tennessee, Veined Italian, Hawkins County Tennessee, and Statuary Italian marble, range in cost in the order mentioned. Fancy imported marbles and onyx are much more expensive. Tennessee marble varies in color from grayish brown to very dark reddish brown, uniformly intermixed with light specks. The Hawkins County marble is bright reddish and white-mottled. All the ordinary materials are cut in stock sizes, and may also be had to order, like the more costly, in any size and shape desired.

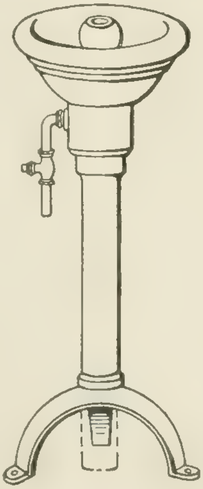


Fig. 22. Drinking Fountain. No Cup Necessary.

The type with apron or skirting, shown in Fig. 23, has legs, and the slab is supported continuously by the skirting. In those supported by brackets or leg-brackets, the strength of the slab is depended upon for support between the bearings. Legs, brackets, and all other metal trimmings should be in keeping with the character and cost of the stone slab. If brackets are properly spaced, the weight is so balanced as to leave very little sagging strain on the center of the slab. A shelf of marble, or a mirror with marble frame, or both, may be fitted above the back as a part of the fixture.

Porcelain and enameled-iron lavatories have bowl, back apron, and soap-cup in one piece. The pedestal of the lavatory illustrated in Fig. 24 is separate, of course, and no back is required, but the general features of integral construction are shown. There are no joints to open. The only injury possible to them is the marring or fracture of the glaze or enamel. Porcelain and iron lavatories, unlike those of marble, are adapted to pedestal support; and some very desirable patterns are therefore made in these materials only. Neither pedestal nor wall lavatories are suitable for use, except where the wall or wainscoting is of marble, tile, or some other waterproof material.

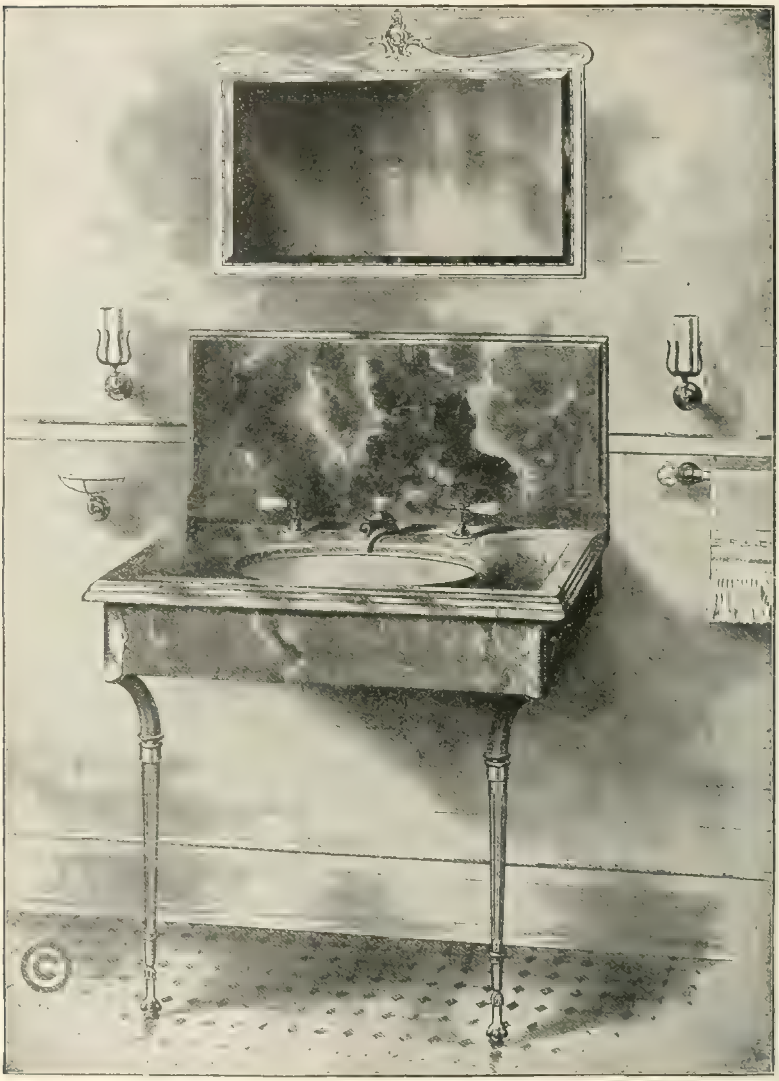


Fig. 23. Brazilian Agate Slab Lavatory, with Apron and Legs.

To provide for leaving the floor clear and free of obstruction, lavatories supported on brackets or hangers, as indicated in Fig. 25, with supply, waste, and ventilating pipes fitted on or into the wall, are best. If found practicable, a neater job results if all pipes leading to and from pedestal lavatories are carried through the pedestal. A supply and waste run to the floor is generally far easier and cheaper to secure than the fitting of all pipes to the wall.

The purchaser seeking iron or porcelain fixtures, has no choice of styles beyond that which the market regularly affords. If he prefers the workable materials, he should insist upon certain features of design which are essential to the best service. Abrupt edges and sharp corners should be avoided; the slab ought to be at least 1½ inches thick, and the back not less than 12 inches high; the general dimensions must be as liberal as space will allow or the service demands (not less than 22 by 32 inches for a 14 by 17-inch bowl); the countersinking must be deep, $\frac{3}{16}$ to $\frac{1}{4}$ inch; the faucet bosses must not join the general border level at all; the faucets must not be less than 12 inches apart, nor so near the bowl that it will be difficult to secure them to the slab; nor may they be placed so close to the back as to make repairing troublesome with any type of Fuller faucets; the joint surface of the bowl must be ground to fit the slab, and provided with not less than four well-drilled anchor-holes for clamps to secure it.

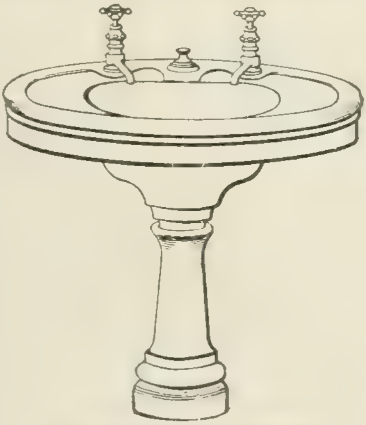


Fig. 24. Lavatory on Pedestal.

Round bowls were formerly quite generally in use, but are now almost relegated to memory. The width of slab needed for a roomy, round bowl is too great; and at best the arms of the user must be cramped in a somewhat vertical and awkward position, while the smaller sizes are very uncomfortable in this respect. The sudden opening of the faucet when the bowl is empty, is likely to ricochet water with annoying results. This is caused by the water striking the curved bowl surface at a tangent, and is not peculiar to the circular bowl; the oval or crescent, or, indeed, any shape of bowl that presents a curved surface to which the faucet stream is tangent, favors the same result; the ovals in integral fixtures are the most annoying. Marble and onyx have an advantage over porcelain and enameled lavatories so far as ricocheting is concerned. The opening in the slab is not so large as the bowl, and thus a horizontal overhanging ledge is formed all around, above the bowl, which generally intercepts the water in a way to keep it off the floor and person. Porcelain and enameled fixtures have not this virtue. The bowl surface, being integral with the slab, is uninterrupted and continuous; hence ricocheting is more violent with them than is possible with the separate bowl.

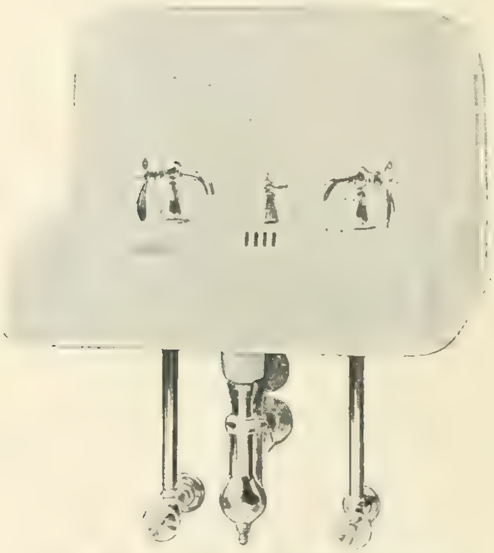


Fig. 25. Lavatory Supported on Brackets.

Oval bowls are now in general use on all types of lavatories. They employ slab space to the best advantage, and are the most convenient for use. The crescent or kidney shape, illustrated in Fig. 26, is, however, as far superior to the simple oval bowl as the oval is to the round. It permits the forearms to lie in a natural and most convenient position when dipping water to lave the face. This form of bowl should be accompanied with a scalloped or recessed front. The D-shaped bowl, and other bowls embracing the prime feature of the D-shape, while not so graceful in appearance, are, without exception, to be preferred, on the score of utter absence of ricocheting when the faucets are properly placed. The D-shape, a transverse section of which is shown in Fig. 27, has a semi-oval front, with the end lines continued parallel some distance past the major axis, and with a straight-line back nearly vertical. This form gives a nearly flat surface in the bottom between the back wall and major axis, on which surface the stream strikes and breaks when the bowl is empty. A depth of water is quickly formed under the stream, which checks any spraying or spattering.

The traps used for lavatories are lead or brass (either cast or tubes), or combinations of these materials, plain or vented or of anti-siphon design. One trouble with lavatory trap ventilation, is the difficulty of obtaining a vertical rise directly above the trap. These vent connections should be carried as nearly vertical as possible, as high at least as the bottom of the lavatory slab, before any horizontal run is made; otherwise the choking of the waste pipe would float solid matters into places from which gravity would not dislodge them. In the absence of water-wash in the vent pipe, these solids would obstruct the vent and defeat its purpose. This danger is not given due attention by many plumbers. The patent and horn overflow bowls, with plug and chain, are the cheapest effective means of controlling the overflow and waste from the bowl. The standing waste, of essentially the same design as the waste fitting for a bathtub, with the body fitting projecting through the slab at the rear of the bowl, is perhaps the most satisfactory waste and overflow arrangement. Various schemes for operating basin stoppers by means of levers and swivels, are employed; but none of them has come into more than limited use.

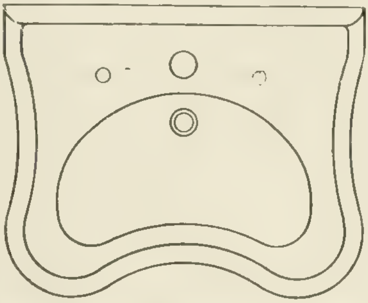


Fig. 26. Plan of Lavatory Slab with Crescent or Kidney-Shaped Bowl.

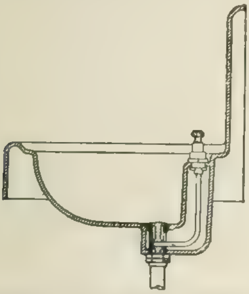


Fig. 27 Transverse Section of D-Shaped Lavatory Bowl.

Basin faucets, aside from special designs, are made on three general operating principles—(1) screw-compression; (2) eccentric action without springs; and (3) self-closing. They are also made in two types—with regular and low-down nozzles. All of these are represented in Fig. 28. The regular type has the nozzle some distance above the base flange, and screws into, or is cast on, the body. The low-down type has its nozzle with a flat bottom, hugging the slab as closely as practicable. The objection to the low-down is the inaccessible narrow space between the nozzle and slab, which becomes filthy and is difficult to clean. High, projecting nozzles obstruct the space over the bowl, especially when washing the hair, but are otherwise most satisfactory. The high nozzle gives trouble with patterns of faucets that separate in the body for repairs, such as the Fuller type, which closes rapidly with pressure. The fault, however, is often that the slab is so shallow as to necessitate the faucets being placed too close to the back to turn without removing the nozzles. If these are cast on, removal of the whole faucet is required before it can be separated. Some faucets are made with union joint in the body, thus avoiding such trouble; but these are not widely used.

The false economy which often dictates the purchase of a small slab, generally also prevails in the selection of its trimmings. Compression faucets close against the pressure, and are slow in action, causing practically no reaction. They are generally responsible for the omission of air-chambers on supplies of medium pressure. On account of their slow action, they are suitable for high pressures although but little weight is given this fact by the trade. The features essential to good, lasting service in the compression faucet, are: a cross-handle, a stuffing box, a raised seat, and a swivel disc. Self-closing faucets of various patterns are made with a view to preventing waste of water, the intention being to compel the user to hold the faucet open only as long as water is needed, and to insure automatic closing when it is released. There are none such except the crown-handled, that an ingenious person cannot find means to hold open at will; yet, withal, self-closing faucets are of great value in reducing wastage. A rabbit-eared faucet can be kept open by placing a ring over the handles while squeezed together; the telegraph bibb, by weighting down or tying up the lever; and the T-handled, while not so easily controlled, can be tied open by a lever secured to the handle. The crown-handled design can be operated with ease by the hand of the user, but does not readily lend itself to unauthorized control by means of a mechanical stop. Self-closing faucets require strong and well-designed springs to close them against the force of the water. They have sometimes come into disrepute through leakage for lack of adequacy in this feature of their construction.

Lavatory supports should have positive means of leveling the slab, such as set screws, screw-dowels, or whatever adjustment the kind of lavatory and support may be best suited to. Lavatory brackets are generally at fault in having limited bearing at the bottom of the wall-face. This point of the bracket is where all the strain is thrown against the wall, and the effect is noticeable if the upper end springs away ever so little. Full-length brackets are not open to this criticism, but they interfere with the washboard or other finish next the floor.

Sinks. These are made in four general classes according to the purpose to be served—namely, Kitchen, Pantry, Slop, and Factory or Wash-Sinks. The materials used are: -Porcelain; enameled, galvanized, and painted cast iron; enameled, galvanized, and painted wrought iron; brown glazed ware; copper; slate; soapstone; various compositions; and occasionally wood. Porcelain and enameled cast iron are most used, galvanized and painted sinks being confined principally to factory use. Sinks of extreme length, in one piece, as shown in Fig. 29, or sectional, 6 to 8 inches deep, with supply and faucets over the center line or at the side, belong to the factory class. These are usually provided with a flat rim, rest on pedestals, and are not over 24 inches wide. There are also roll-rim patterns, with bracket support and iron back, and with faucets fitted through the back. These are generally 8 inches deep and about 20 inches wide.

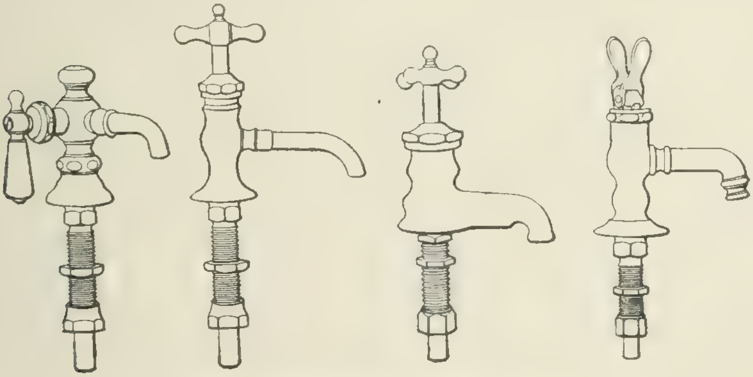


Fig. 28. Common Types of Basin Faucets.

Kitchen sinks vary in size according to general requirements. Common sizes are 18 by 30 inches and 20 by 30 inches. The depth ranges from 6 to 7 inches. There are two types of iron sink flat-rim, with outlet at end; and roll-rim, with outlet in center. Neither style of outlet is always desirable as to connection; but the center outlet drains more directly. The flat-rim type is not provided with legs. Cast legs were formerly furnished, being attached to the sink by slipping into dovetails. When legs are desired for this type, the plumber provides gas-pipe legs, with or without a top frame. Iron splash-backs are provided for flat-rim sinks, but not of the deep pattern in which air-chambers may be cast. Plumbers drill these sink rims to attach brackets or legs, and sometimes also to secure to them hardwood capping or drainboard. Hardwood drainboards are generally provided by the plumber's carpenter. Hardwood splash-backs, set free of the wall to permit circulation of air behind the fixture, are also provided. Sometimes marble splash-backs are provided. Marble is best, but is not in keeping with a flat-rim sink. The back may extend to the end of the drainboard, or merely cover the length of the sink. Omitting the back behind the drainboard, as represented in Fig. 30, is often thought desirable. The drainboard should be free of the wall when the back is not extended. Iron sinks, with roll rim on front and ends, are furnished with drainboards suited to attach to either or both ends. These may be added as an after-consideration, or changed from side to side at will, if there is but one drainboard, or removed entirely, without marring the looks or service of the sink. This interchangeability commends itself to both plumber and customer.

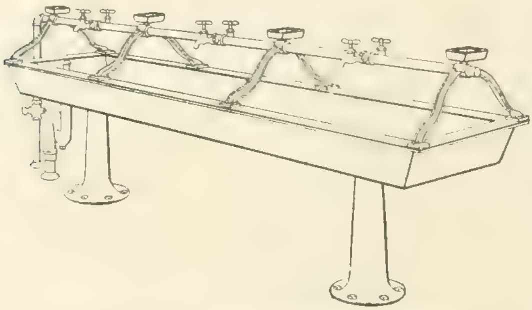


Fig. 29. Long Wash Sink for Factory Use

Roll-rim sinks, with the end recessed to receive a drainboard, are also made, which give good service, but in any subsequent change of location require setting in the original relative position.

Wooden drainboards, with an iron end to attach to sink, and enameled-iron drainboards, are furnished if ordered.

Open strainers are most frequently fitted to sinks, in which case the sink cannot be then used for washing dishes, but merely serves as a support for dishpans and other vessels and as a catch-all for drippings from the drainer. Hence the open-strainer sink must be large enough to accommodate suitable washpans, etc., while one fitted with a plug-strainer should be relatively small if it is designed to use the sink proper as a washpan.

The use of wooden sinks in large installations, such as hotel kitchens and restaurants, is not unusual, the theory of their use being that less breakage of crockery occurs, by reason of the softness of the material. The argument against the use of wood is not given due weight in this connection. The well-recognized objection to any porous, absorptive material which retains moisture and is subject to decomposition, is especially to be considered in the use of wood for greasy wastes. For the reason mentioned, wood is never a suitable material for this use.

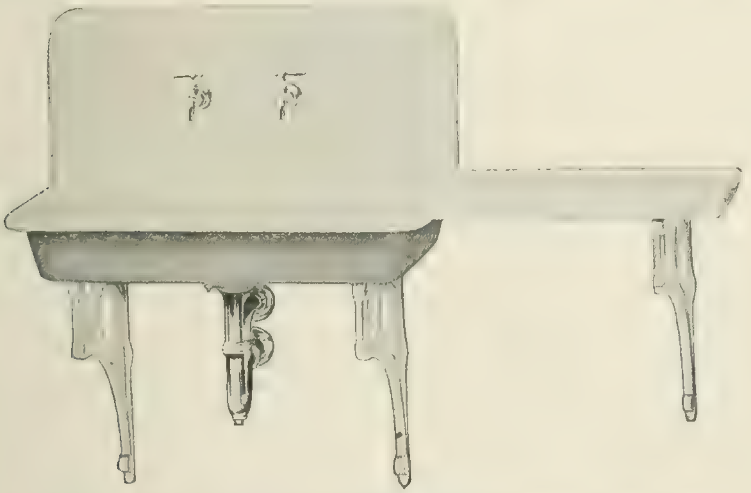


Fig. 30. Enameled-Iron Kitchen Sink Supported on Brackets. Splash-Back Omitted behind Drainboard.

Rubber mats are essential for both sinks and drainboards having enameled or glazed surfaces, in order to avoid accidental injury to the articles cleansed. As a matter of fact, the average dwelling has but one sink, which serves both kitchen and pantry purposes. Dual service is not always satisfactory, however, as no sink can be well adapted to both uses for a large family. A plug-strainer sink should also be provided with an overflow.

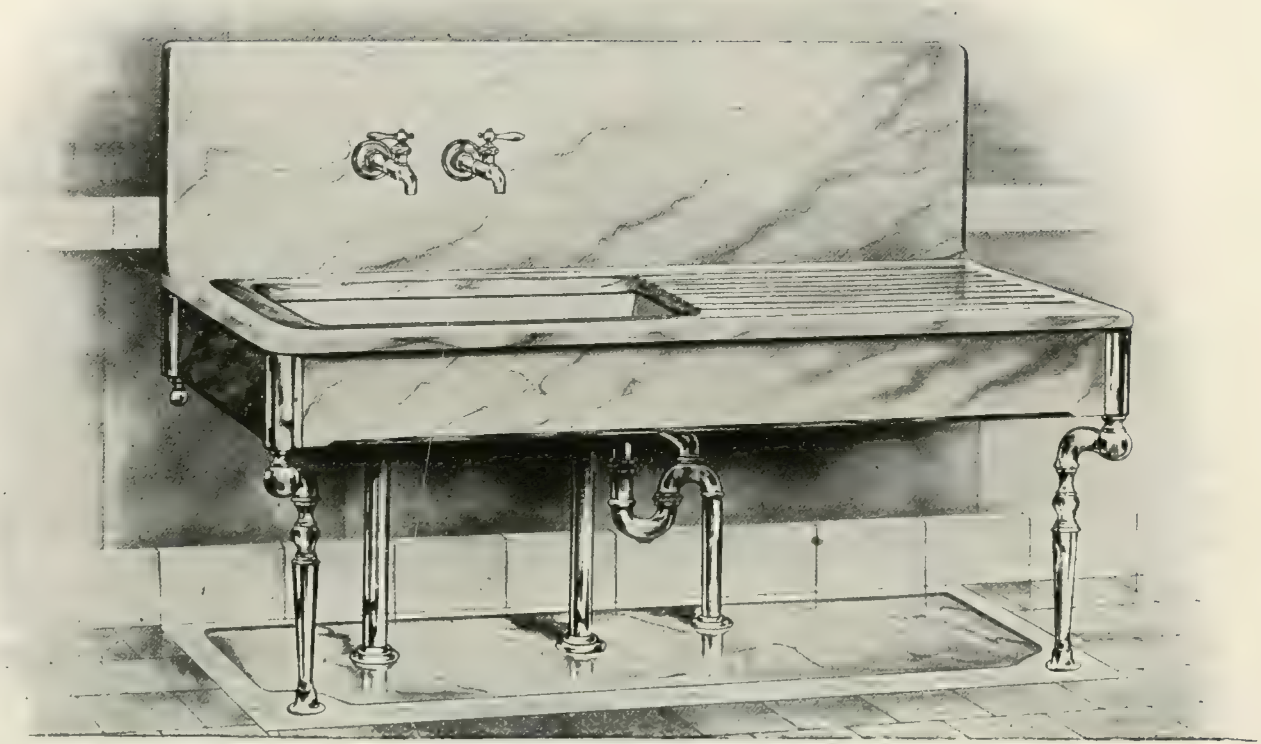
Porcelain and iron sinks have generally been supplied with loose backs; but sinks of one piece—that is, with sink and back integral—are now obtainable. Sinks with integral apron or skirting all around, to be placed free of the wall, are suitable for installation where the wall is waterproof.

Sinks are built from slabs of natural stone as desired, and may be with or without drainboard or skirting. They are generally provided with a high splash-back. These sinks are not limited to the patterns of a moulding room, and easily keep pace with the desires of the purchasers. Selection is confined to a choice of material, as every desirable type of fixture is easily supplied.

In the use of any natural stone, such as slate or soapstone, for plumbing fixtures, and especially for sinks, it should not be forgotten that angles and rectangular corners are with difficulty maintained entirely free from deposit. Although the flat surface can be readily scoured, it is always difficult to clean the sharp angles and corners satisfactorily. The difficulty is increased by the fact that some plastic jointing material, such as putty or cement, must be used in putting together the fixture; and small fragments of this material project into the angles and render the corners rough. Stone and porcelain sinks are heavy, and require careful packing for shipment.

Air-chambers may be cast in iron sink-backs. The ordinary sink-back is not well suited to the convenience of the plumber where supplies to any fixtures pass up behind the sink. The faucet-holes cannot be changed, and slots for pipe are not provided at the top edge. Sawing these gaps after the goods are enameled, leaves the fixture with an unfinished appearance. The proportion of shank to the handle of faucets of the Fuller pattern used on sink-backs, must be such that the handles will turn straight back.

A popular fixture of comparatively late design, adapted for small dwellings and now made in the cheaper materials, is the kitchen sink in combination with a single laundry tray, an example of which is shown in Fig. 31. In this, the drainboard serves as a cover for the tray when the sink is in use. Sinks have also been supplied in combination with lavatories, one sink being placed in the center or at the end of a battery of lavatories.



ITALIAN MARBLE KITCHEN SINK.
The Federal Company

A pantry sink (Fig. 32) should always be provided with a drainboard. It is a smaller fixture than the kitchen sink, and is nearly always of the plug-strainer and overflow type. Its faucets are generally of the high-nozzle type, like those for shampoo purposes, but of smaller capacity and better adapted to rinsing than are kitchen-sink faucets. Indeed, the pantry sink proper need not necessarily differ at all from sinks used for other purposes. Every feature of its trimmings and setting is intended to best serve the butler's needs.

The waste matter from the butler's sink is not like that from the kitchen sink; hence the waste pipe is not necessarily so large, nor is a grease-trap so badly needed. Grease in considerable quantities finds its way into kitchen-sink waste pipes. It floats on the stream of waste water as it travels through the pipe, and, being always next the interior surface, either adheres thereto on contact, or by a reduction in temperature is chilled and congealed, thus clinging to the pipe walls. Successive layers of grease are in this way accumulated, and the bore of the pipe is finally reduced so much that solid matter easily completes the stoppage. Forcing out, and then filling the pipe with boiling lye water, and again flushing with hot water, will usually remove most of the obstruction. Sometimes the lye loosens the grease in chunks, which clog the pipe seriously at the first favoring point, and the pipe must then be cleaned manually.

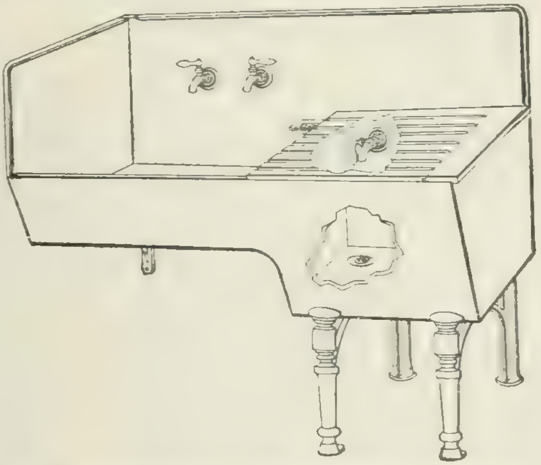


Fig. 31. Kitchen Sink and Single Laundry Tray Combined.

When once choked with grease, the pipe must ultimately be opened and cleaned by hand, often at material expense when long lines are deep underground. To avoid this trouble, various traps (of which two examples are shown in Fig. 33) have been designed to separate and collect the grease, either by flotation or by chilling—generally by the former. Traps to collect the grease by flotation were formerly improvised by the plumber, being placed in the drainpipe just outside the building. This location left too much pipe subject to choking between the grease-trap and the sink; and the trap itself often became a generator of bad odors in warm weather.

The grease-traps now commonly furnished are placed in the kitchen under the sink, and frequently serve as the regular trap for the fixture. The grease is easily removed by lifting out the container or by skimming from the top. Hinged bolts with thumb-nuts secure the covers so that they can be easily and quickly opened and securely closed.

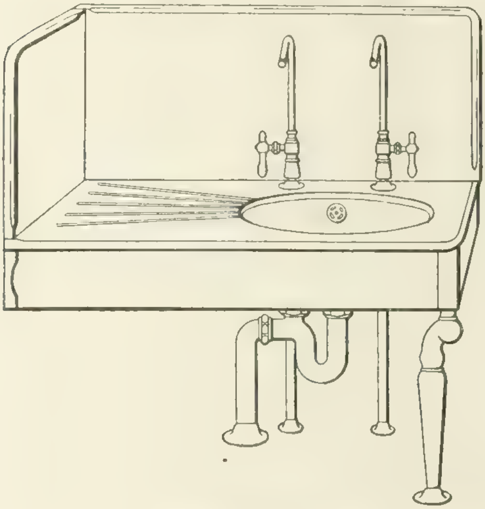


Fig. 32. Pantry Sink.

Traps which chill the grease are not used so much as those acting by simple flotation, but they do the work perfectly. The chilling process is accomplished by means of a water jacket through which the cold-water supply passes. The water entering low, surrounds the wall of the pot trap within, and passes out high up on the opposite side (see fixture at left in Fig. 33). Circulation—or, rather, change of water—in the jacket, is dependent on the amount of water used at the fixtures.

The usual slop sink is 18 by 22 inches and about 12 inches deep. Generally it is furnished mounted on a trap standard, as in Fig. 34, which serves the double purpose of support and waste-trap.

Care should be taken before installing a fixture placed upon a trap standard, to examine carefully whether the seal of the trap is provided for by suitable interior partitions. It is not uncommon to find defects in the casting, if of iron or brass—or in the porcelain, if of that material - which would seriously affect the maintenance of the water seal. In fact, it is desirable in connection with slop sinks, as with all other fixtures, that the trap be of such a form as to show clearly, even after being set in place, the position of the various portions which constitute the trap and maintain the water seal.

The waste pipe is never less in diameter than 2 inches, and is usually 3 or 4 inches. The outlet is invariably through an open strainer.

Slop sinks are made in all the materials common to other fixtures except natural stone. These sinks are to the chambermaid what the kitchen sink is to the cook. The shape and liberal-sized waste are well adapted to removing slop and scrub water. In the complete fixture, the sink is provided with an elevated tank and flushing rim, to cleanse the fixture walls; also with hot and cold supplies for drawing water, rinsing mops, etc. The supplies usually connect between the valves, and terminate with a long spout with pail-hook and brace. The spout supports the pail over the center of the sink while filling. The ordinary slop sink is provided with hot and cold faucets; and as the rims of the cheaper kinds are plain flanges, no tank flushing is possible.

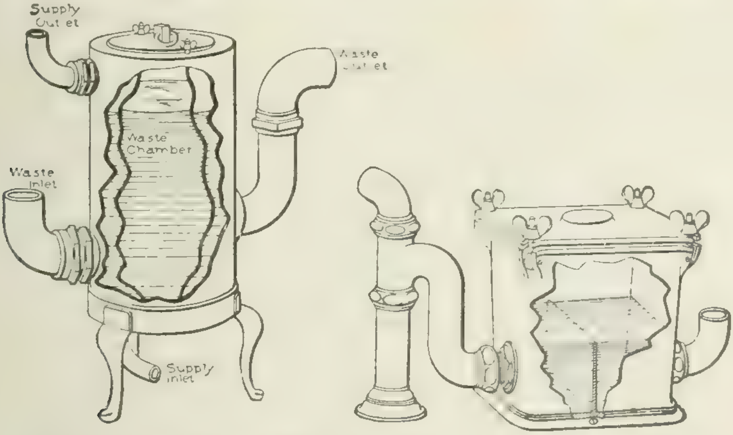


Fig. 33. Types of Kitchen Sink Traps for Separating and Collecting Grease.

Laundry Trays. These are made in all the materials used in other plumbing fixtures. Wood trays were formerly common but their unfitness because of absorption and odors, coupled with the increase in cost of lumber and the lessening in cost of the better materials, has effectually driven them out of the business.

The same inherent objection to the use of wooden covers may be urged as to the use of that material for the body of the fixture.

Trays are made singly and otherwise, but generally used in sets of two or three, except in the combination with sink already described. They are supported by a center standard or a metal frame, as best suits the material used.

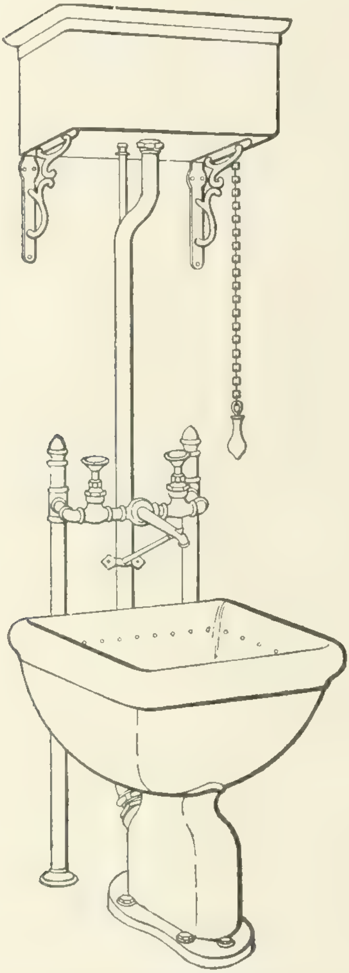


Fig. 34 Slop Sink Mounted on Trap Standard.

Some means of attaching wringers are provided, if possible. The waste is usually 2-inch. One trap answers for a set of trays. The size approximates 26 by 30 inches at top, with 15 inches' depth. The walls are all vertical except the front, which inclines about 30 degrees, making the width at bottom considerably less than at top. Some makers furnish one tray with each set, designed to serve as a washboard, the interior of the front wall being corrugated like the surface of a portable washboard. The inclination of the front is about right for scrubbing, whether the tray or an ordinary board is used, and the supports place the top of trays convenient to the work.

All trays were formerly made with faucet-holes in the back; and the plumber furnished a hinged cover. Side-handle faucets were necessary to allow the cover to close, as holes for top-handle faucets would be so low as to make useless too much of the space above them. The faucet-holes were seldom fitted water-tight. Holes are not now made in trays unless ordered, and the side-handle wash-tray bibb is disappearing. They were always annoying. If placed with the handles right and left as intended, the seat could not be examined, and no reaming or dressing of the faucet seat could be done without removing the faucet. When placed with the faucet handles facing each other, they were wrong-handed and too close together. It was awkward to supply air-chambers—especially so when all the faucet holes were equidistant from the top. When placed for one line of supply above the other, one line of holes was too low. These objections combined brought about the practice of omitting the covers, putting the supplies over the trays, and using regular sink faucets. Overflows are provided only when so ordered.

Enameled backs with air-chambers and faucets are supplied with roll-rim enameled-iron trays. A complete set of three trays, with all attachments and fittings, is shown in Fig. 35. Flat-rim trays are made with or without faucet-holes, and are intended to have a hardwood frame to secure them rigidly. The wood frame and cover can be had with the fixture, but the plumber often supplies them. Nickel-plated or plain brass wastes and traps are furnished for trays, but the plumber can provide lead or cast-iron waste, if wanted.

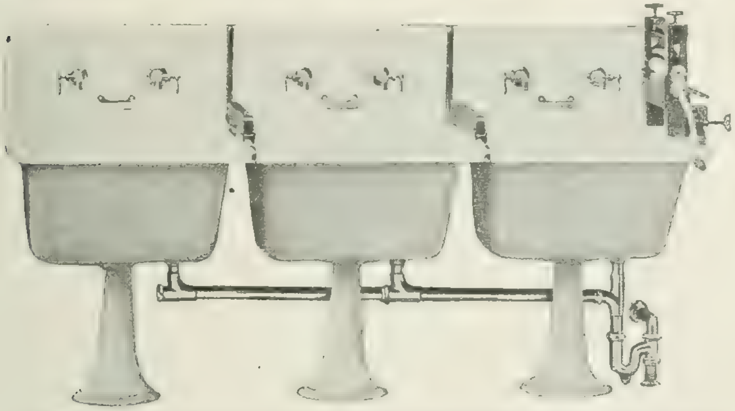


Fig. 35. Set of Three Laundry Trays, with complete attachments and Fittings.

Water-Closets. Types of water-closets are innumerable, and are separable into classes according to principles of action. Porcelain and painted or enameled iron are the materials used. Porcelain is more fragile, but has the better finish and is susceptible of a greater variety of design and ornamentation. The all-vitreous body of water-closet china of to-day is far superior to the glazed clay ware of the past, which, depending only on surface impermeability, soon cracked badly, thus permitting of absorption, the forerunner of odors which no plumber's skill could prevent. Enameled iron has not so durable a surface, but will stand rough usage, and has the advantage of very seldom cracking from frost even though the water in the trap freezes.

The greater relative advantage and durability of the porcelain closet over the best qualities of enameled-iron fixtures, should not be overlooked. There is less adherence of the foul wastes to a porcelain surface than to the enameled surface. It is also a fact that enamel is subject more or less to abrasion by the use of harsh scouring materials, as well as to decomposition by uric acid and water-closet discharges, and is therefore not a very durable material. These statements can be confirmed by observation of closets which have been in use for a number of years.

Iron closets of the better forms are used most in public places, stores, warehouses, etc. The pan closet, of iron, with earthenware bowl, is not now installed. For these, a trap was placed under the floor. The pan, operated by the same lever as the flushing valve, retained water, partially sealing the body from the bowl. The flush was by the swirling of a stream which entered tangentially under the rim. The bowls were round, as is necessary in all hopper closets thus washed, for water will not swirl in an oval bowl.

The objection to the pan water-closet is principally due to the fact that the outer bowl or container is a receptacle of filth which can never be properly cleansed. When the pan deposits its contents in the lower portion of the fixture, a considerable amount of the filth is spattered upon the walls and is not subject to the cleansing effect of the stream of water which scours only the upper bowl. When the closet is operated, the odors from this concealed surface permeate the room in an objectionable manner.

Tall round hoppers with swirling supply are yet frequently used in outhouses and other exposed places. No other form of closet will stand such locations under like conditions. The waste-trap is not placed immediately under the hopper, as in other forms, but down below the freezing depth—five feet as a rule. The supply valve is also placed below freezing, and is operated by a pull or by seat-action. These closets are *continuous* or *after-wash*, according to the style of valve used. Such an outfit is the simple frost-proof closet of the market. Tall oval hoppers with valve and slotted spud attached, swirl or rather direct the water sideways in both directions, but not effectively. The tank supply is also inefficient when delivered through a slotted spud under the common flanged rim. Short oval and round hoppers, with valve or tank supply operated by a pull or by seat-action, fitted to "S," "$\frac{3}{4}$ S," and "$\frac{1}{2}$ S" or "P" traps, for lead or iron pipe floor connection, make up several hundred closet combinations, each differing in some respect from the others. These are the poorest types of water-closet.

A sectional view of the *Combined Hopper and Trap* pedestal of to-day is shown in Fig. 36. It is made in one piece, in both porcelain and enameled iron. This form resulted from the separate hopper and trap fixtures before mentioned. The combined form has oval bowl and flushing rim for tank supply.

The *Wash-out* closet is a modification of the combined hopper and trap, being formed with a dipping bed under the mouth of the bowl, which retains enough water to keep soil from sticking to the surface. The water-bed makes it necessary to discharge the contents at either front or rear of bowl. The back-outlet wash-out is most repulsive to view; in them the drop-leg, which the flush never washes thoroughly, is always in view, so that its filthy condition suggests cleansing by hand. The front-outlet wash-out, shown in section in Fig. 37, is of more inviting appearance; but the drop-leg, although hidden, is there just the same.

Both the Wash-out and the Combined Hopper and Trap types have one fault in common. The trap almost always contains the soil from one usage. When the contents of the trap are flushed out after using, sometimes a similar mass refills it. Of course, two or three consecutive flushes would leave comparatively clean water in the trap, but this is not to be expected in regular usage.

On certain occasions the wash-out may serve a useful purpose on account of the water-bed. The stools of children or the sick may thus be easily observed at the will of the physician or at the discretion of those in charge, while such is impossible where the soil is submerged at once.

Pneumatic Siphon closets of various types have been put on the market. A good example of the type requiring two traps with an air-space between, is shown in Fig. 38. A specially constructed flushing tank is connected with the air-space between the traps The falling of the flush water creates a partial vacuum in the bottom compartment of the tank, which induces siphonage of the bowl contents.

To maintain a plenum in the flushing compartment of the tank while the flush water is flowing down and into the closet, the air between the traps is extracted, being drawn up through the air-pipe into the tank. Atmospheric pressure in the room simply presses the water out of the bowl and upper trap when the pressure below it is sufficiently reduced. This water, in motion, added to that of the lower trap which has been drawn above its normal level in response to the vacuum, is sufficient to form the long leg of an ordinary siphon; and thus both traps would be entirely emptied were it not for the vent in the crown of the lower trap breaking the siphonage in time to save a water seal for the lower trap.

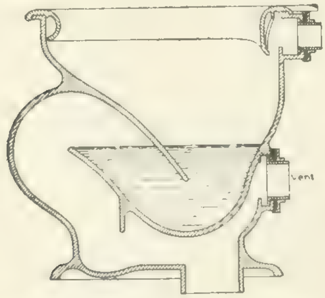


Fig. 36. Section of Combined Hopper and Trap Closet.

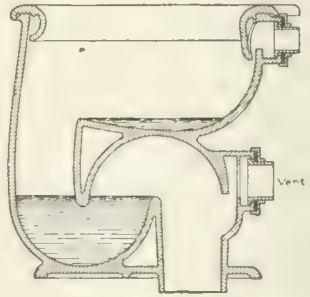


Fig. 37. Section of Front Outlet Wash-Out Closet.

The upper trap with water visible in the closet bowl in repose, is supplied by the *after-fill*, thus establishing conditions for the next action. The lower trap of such closets must be back-vented, and it is essential that the upper trap have no back vent.

The proper action of the tank is necessary to operate a pneumatic closet. A closet constructed on any other principle can be flushed with a bucket, by hand, if its tank is out of order. When a pneumatic closet, however, gets contrary, pouring water into the bowl simply fills or overflows it. The outlet is air-bound, and no passage of water to the soil pipe can take place until the barrier of air between the traps is removed.

The closets now accorded first place and generally used in the best work, are of the *Jet-Siphon* type, illustrated by the sectional view, Fig. 39. These use more water than is necessary to flush other kinds of closets, because a portion of the water is employed to produce the siphonage. A channel leading from the flush-water inlet to the bottom of the trap, conveys a stream of water to the trap leg, and injects it upward therein. The water in the channel has considerable velocity, and, being discharged into the water in the trap, imparts its energy to the whole mass, which, aided by the rise due to the incoming water from the flushing rim, moves upward at an increased speed depending on the ratio of mass and jet. When the water in the trap has been lifted in this way to an extent where sufficient of it can fall over the weir into the out-leg of the trap, a siphonic movement begins, and true siphonage finally takes place, the cessation of which depends upon the lack of sufficient water to continue it. Before the closet tank is emptied, siphonage often sweeps out the trap thoroughly; and what water falls back into the bowl when the siphon breaks, together with the incoming jet and flush, causes a second siphonage.

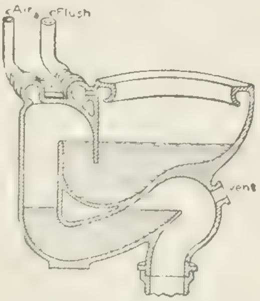


Fig. 38. Section of Pneumatic Siphon Closet with Two Traps and Intervening Air-Space.

Accuracy in pointing the jet and in shaping the surfaces of its environment, are essential. If the surface above the jet-hole favors interference by the water flowing from the bowl, siphonage will be delayed and abortive, and may not take place at all. So, also, if the jet is not directed so as to maintain approximate concentricity in its travel through the mass of water, its energy is not expended to advantage, and failure is likely.

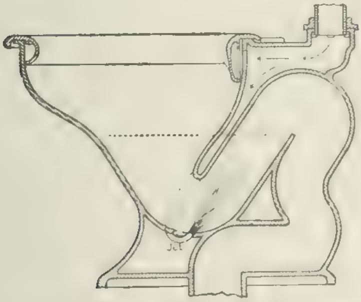


Fig. 39. Section of Jet-Siphon Closet.

There is no excuse for iron closets not siphoning perfectly. The iron pattern can be altered until it gives the best effect in practice, after which all closets cast from it should do the same. With porcelain ware, however, every closet made requires the same skill in design; and notwithstanding how perfectly the closet may be formed and the jet-hole cut, shrinkage in the kiln during the drying and burning process is apt to warp the wall and change the product so that it will not act properly. Closets of both materials, apparently perfect, often fail when first tried after installation, owing to foreign matter or fragments of enamel, clay, or iron lodging in the jet and changing its action. Usually these obstructions are easily removed by the plumber.

The jet principle has been added to the Combined Hopper and Trap closet before mentioned, producing in it a siphonic action resulting in very much improved service over that of the simple form. With the jet-action, the Combined Hopper and Trap is generally termed a *Wash-Down Siphon.* The so-called "jet" is applied in two ways. In some makes, the flush rim has an extra large and specially formed fan-wash feature, which directs down the back wall of the bowl a sluice-like stream. This stream, in addition to wetting the paper and forcing it down into the water, where it will be promptly carried out, sweeps round the curve of the bowl outlet in such a way as to lend its force to the water in the trap to produce apparent and not infrequently true siphonage.

Another form of the wash-down siphon is provided with a channel from the flush inlet, down outside the back wall of the bowl, to near or even below the water-level in the bowl, where the jet enters through a slit. The action is much the same as with the special fan-wash mentioned, but is generally superior in siphonic effectiveness.

Jet-siphon closets are not provided with vent openings in the closet proper, except for the local bowl ventilation. Wash-out traps are, or should be, vented. The simple hopper and trap should be vented in the trap. Wash-down siphons, generally, are not vented, but it is permissible to vent them low down in the outlet leg of the trap.

All closets for indoor use should have flushing rims. In all earthenware closets and in some forms of iron closets, the rims are made integral; but the iron rims are, as a rule, separate pieces, forming a water channel around the bowl. The bottom, inner edge of the iron rim hugs the wall of the bowl as closely as practicable, and the bulk of the water falls through regularly spaced serrations. Various provisions in the shape of barriers opposite the flush inlet, perforated race-way shelves along the rim above the exit openings, etc., are made to insure the rim filling and flushing properly all around.

All kinds of closets were formerly made without regard to the kind of seat to be used. Boxed-in cabinet seats, self-supporting, were universal. These gave way to seat and frame, with wall and leg support. To-day closets are commonly made with base flanges designed to support the weight of the person, and are provided with lugs or seat-shelf for attaching the seat directly to the bowl, as seen in Fig. 40. Metal post hinges are best in every way, if well made and strong. The competition goods, however—made to sell rather than use—*are* so light as neither to keep the seat in place nor to aid in holding it together under the severe strain. The hinged wood-cleat seats bolted to the closet are strong, but are objectionable because they cannot be kept dry or clean under the cleat.

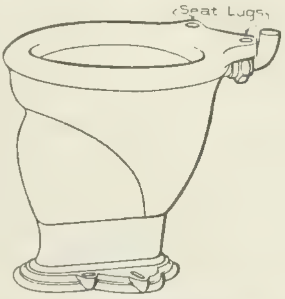


Fig. 40. Closet with Base Flange Support, and with Lugs for Attaching Seat.

Closets are operated with pull or push-button tanks requiring the attention of the user; and are also made of the seat-action type. Children are likely to be forgetful, and visitors to public toilet rooms indifferent, to such an extent that automatic closets are desirable for public places and schools.

Closets are fitted with two styles of tanks—one placed about 7 feet from the floor and serving with a flush pipe never more than 1½ inches in diameter; and the other placed low down, as close to the bowl as connections will permit. Examples of the *high-tank* and *low-tank* arrangements are shown in Figs. 41 and 42, respectively. The low tanks are wider and deeper than the high style, but do not extend out from the wall so much. The low position delivers the water at much less velocity than the elevated style, and, to secure the utmost speed and the volume necessary, the flush connection is never less than 2-inch in a low-tank closet. The rim and jet channel are proportionately larger in bowls intended for use with low tanks. High tanks are about 17 by 9 by 10 inches. Sheet lead and sheet copper are used for closet-tank linings. Some kinds of water, through galvanic action, attack the soldering of the seams in copper-lined tanks with more effect than where lead alone is used. Generally, however, copper-lined tanks give satisfaction if the copper is heavy enough (12 to 16 oz.) and properly put in. Some makers lock-seam the linings water-tight, and solder on the outside before placing the copper in the wood case.

On account of the greater depth of low tanks, swelling of the wood case has, doubtless, been the cause of most of the trouble experienced with this type. When put together in the factory, the wood is very dry, and after being used for a short time, increases in height as a result of swelling from dampness. If the lining be tacked to the wood at bottom and top, injury is sure to result. If tacked at the top only, the copper will soon be supporting the water without help except where the connections are attached. It is now the practice to omit fastening the lining. Very great care has been found necessary with ball cocks for low tanks, in order to secure proper after-fill, the flush connection being too short to aid much in resealing the bowl with its drainings.

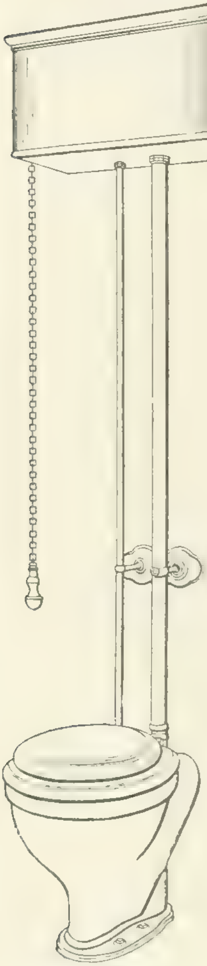


Fig. 11. High Tank Arrangement of Closet Fixtures.

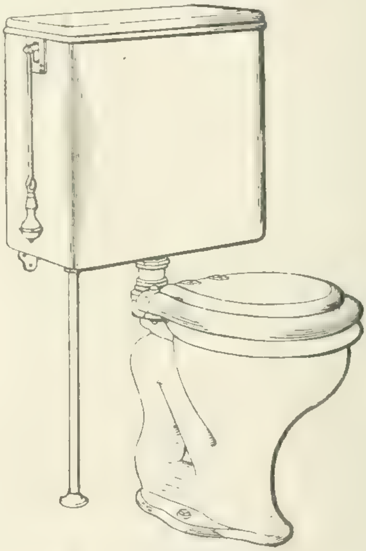


Fig. 12. Low Tank Arrangement of Closet Fixtures.

Low tanks flush with much less noise than high ones, and permit placing the closet under windows and low ceilings. Low ones require more width on account of the tank, and more depth from the wall to the front, as the seat and lid must be placed far enough forward to be thrown back and remain leaning against the front of the tank. Low tanks are provided with ventilated covers; while the high pattern, which is out of children's reach, is left open at the top. The fewer working parts in a tank, the less likely it is to get out of order.

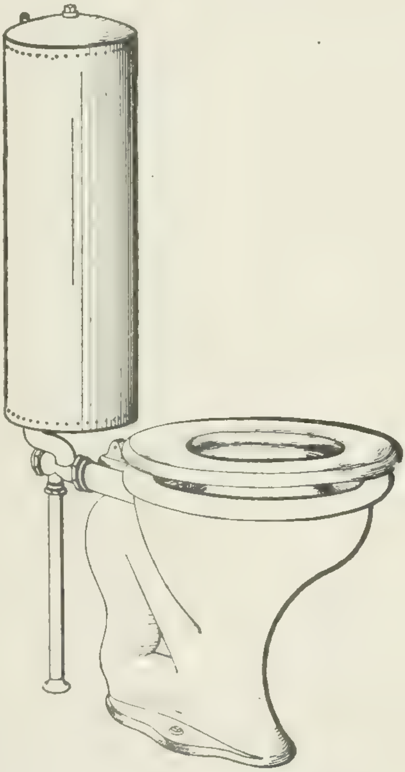


Fig. 43. Seat-Action Closet with Closed Metal Tank.

A type of seat-action closet very seldom placed in private houses, is that with closed metal tank, as represented in Fig. 43. Depressing the seat opens a valve in the supply, and the water passes up through a flush pipe into a closed tank. The air in the tank is compressed until the air-pressure counterbalances that of the water. When the seat is released, the supply valve closes; and a valve is opened, establishing communication between the closet and the tank. The compressed air then expels the water in the tank, flushing the closet just as a large supply with corresponding pressure would do without a tank. Closed-tank closets depend on pressure. The space occupied by the air in the tank is inversely proportional to the pressure; hence, even in heavy pressure, considerable of the tank's capacity is yet occupied by air when equilibrium is established; and the less the pressure, the smaller the amount of water it is possible to get into the tank. They are therefore not fit for very light pressures, though they sometimes serve well in the basement of a building where failure would be certain on the upper floor.

Condensation on metal tanks is annoying. Open tanks of porcelain and iron are used more or less, but sweating is hard to overcome. Zinc paint and ground cork finishes have been employed with some satisfaction; and drip-cup collars discharging into the flush just under the tank have served in this capacity, but nothing overcomes the sweating so well as a tight wood case, insulated metal cases not excepted. Some makes of the pressure-tank closet require too much weight on the seat for successful operation by a child, and children would as a rule leave the seat too soon to allow the tank to fill reasonably well. The flush pipe of pressure closets is from a few inches to four feet in length. The after-fill is accomplished by projecting the flush connection into the tank an inch or more, and drilling a ¼-inch hole or less through it near the bottom of tank. The rapid flow ceases when the water-level falls to the upper end of the inward-projecting flush connection, and the after-fill drains into and down the flush slowly.

The flush fittings of an open tank consist essentially of a valve to admit water to the flush pipe; an overflow always open to the flush pipe; and a lever and connection, with chain and pull or button, to open the flush valve. A simple example of these is the siphon gooseneck, with flush-valve disc on one end and lever connection at the other. Prongs extend below the disc to guide and keep it in place. The overflow is through the gooseneck. Lifting the gooseneck an instant permits enough water to flow down the flush to start the siphon through it when the pull is released. The tank then siphons to the lower end of the gooseneck arm.

Where shortness of flush pipe or form of closet requires a decided after-fill, this is secured by special provision in the flush fittings, or by leading some of the supply delivered by the ball cock into the overflow.

The supply fittings of a closet tank consist merely of a ball cock of suitable form. For light pressure, simple leverage suffices. For heavy pressure, the inlet in the valve would have to be too small, or the ball too large and stem too long, for a small tank, if simple leverage were employed. Therefore compound-leverage cocks are usually substituted where the pressure contended with is over 30 pounds. There are ball cocks made in which the buoyancy of the ball merely operates a small secondary valve in a way to establish the initial pressure over a disc of larger upper surface than that of the under side which covers the main water inlet of the cock. The disc is thus effectually seated, regardless of the pressure; and a 4-inch ball may be arranged to close almost any size valve against any pressure.

When the cock is attached through the bottom of the tank, no precaution against sound is necessary. When the cock is fitted in high up, a pipe from the delivery is extended to near the bottom of tank for the purpose of muffling the sound of the water as it fills the tank. An unmuffled delivery and a high-tank flush make considerable noise when the closet is flushed, and are suggestive and very embarrassing to sensitive people. Silent action is therefore the goal for which many strive. Silence at the expense of thoroughly washing the closet surfaces and flushing out the contents, is not desirable; some noise is necessary to the rapidity of action essential to thorough scouring and evacuation.

Tanks requiring the flush valve to be held off the seat during the entire flush, are now no longer installed. Perfect silence in the flush pipe of a high-tank closet has been obtained by a type of flush fittings that permits the pipe to hang full of water. The flush valve being opened, water begins to flow into the closet immediately. When the valve closes, no air having access at the upper end of the flush, the pipe remains filled. The flush valve of such a closet must close absolutely water-tight to prevent continual dribbling into the bowl.

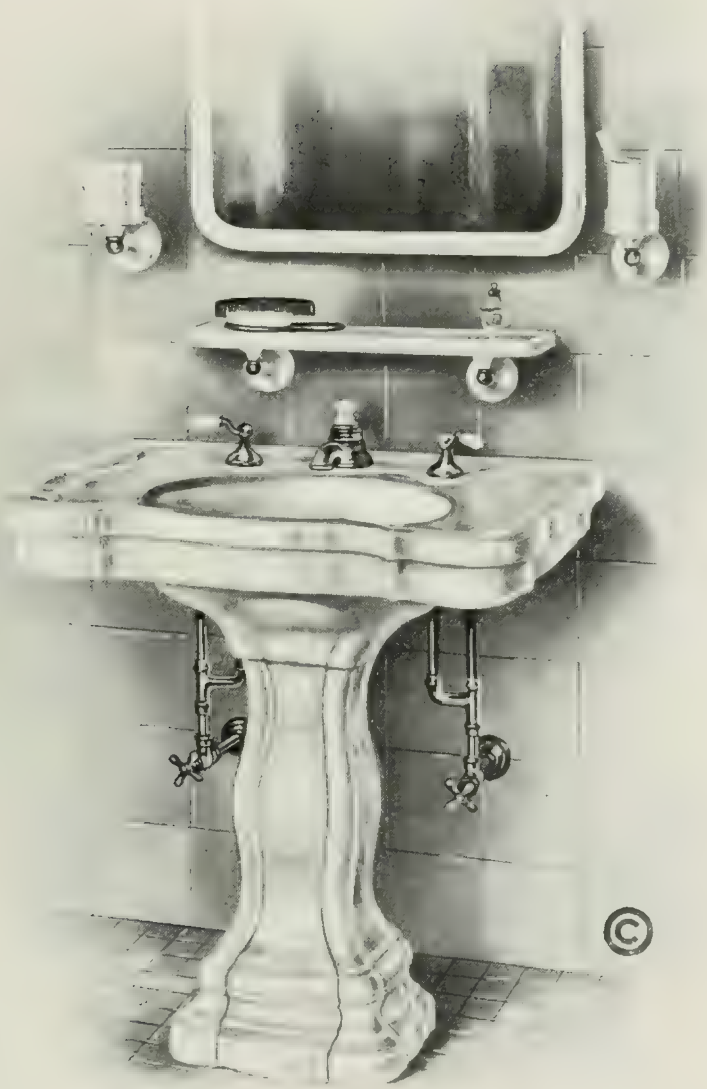
Of late years, direct-flushing valves of many forms have been a feature of water-closet design. These valves make the individual closet tank unnecessary. Direct-flushing closets, a type of which is shown in Fig. 44, have the same advantage as the low tank in the matter of being placed where high closets cannot conveniently be arranged. A check to their more general adoption has been the lack of large supplies in residences and other buildings.

The possibility that the house system of water supply may be contaminated from the water-closet if the water supply is directly connected to the water-closet fixture, should not be overlooked. Although this contamination is more likely to take place in the operation of the older types of closets, such as the pan closet and the plunger type, it is not of rare occurrence in connection with later types, especially the so-called *frost-proof* fixture. If the pressure is materially lowered in the street main by accident or otherwise, it sometimes happens that water may be drawn back into the house system by siphonage from a water-closet or like fixture, thus of course incurring the possibility that germs of disease may be brought into the water supply used for domestic purposes. The use of a tank into which the water is first drawn, obviates this danger.

The ordinary dwelling or storehouse supply can be made to operate successfully by placing an accumulating chamber on the branch to the closet, and having a check-valve on the street side of it, so that the water cannot flow back when the pressure falls as a result of drawing at other points. In such cases the pipe between the accumulator and the closet must be the usual 1½-inch size. Closets thus fitted are really only pressure-tank closets with the flush controlled by a direct-flushing valve to be operated at will instead of automatically by seat-action.

In all tank installations, the direct method is easily employed by carrying the proper size flush main directly to the closets, independently of the supply for other fixtures. This is recommended in buildings having numerous closets. One tank, with large flushing main, will serve all the closets, and thus the individual tanks and equipment are not needed. Furthermore, no trouble is then experienced in providing suitable space for the small tanks. The flushing valves may, if desired, be placed out of sight, and only the operating lever brought to view in a convenient position. A flushing valve has been made which, like the secondary-valve ball cock, works on the old Jennings diaphragm principle, using a "time" filling cup to establish the initial pressure over the diaphragm. Releasing the pressure over the diaphragm by means of the operating lever, opens the main channel and causes the closet to flush while the time chamber fills again.

In this country and most others, the height of closets has always been uniformly 16 to 17 inches to top of seat. It is claimed that this height results in an unnatural position, and individual opinions against it have been voiced from time to time with little effect. Lately, however, more earnest attention has been given the subject of height, and there has been designed a closet considerably lower than usual, with the top sloping down toward the back. This form, it is said, induces the user to assume an upright position of body, relatively more closely conforming to that of the limbs, and favoring



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unrestricted action of the intestines. It remains to be seen whether this form will result in any general departure from the old lines.

Closets often also serve as urinals, especially in private houses. For limited service, this is not to be considered an actual abuse of the fixture, though general use of distinct urinal fixtures is indispensable.

Range Closets. Batteries of individual closets are usual in office buildings and many other such structures; but in schools and in many public places open to all classes, ranges divided into stalls or compartments have been considered a satisfactory solution of the problem.

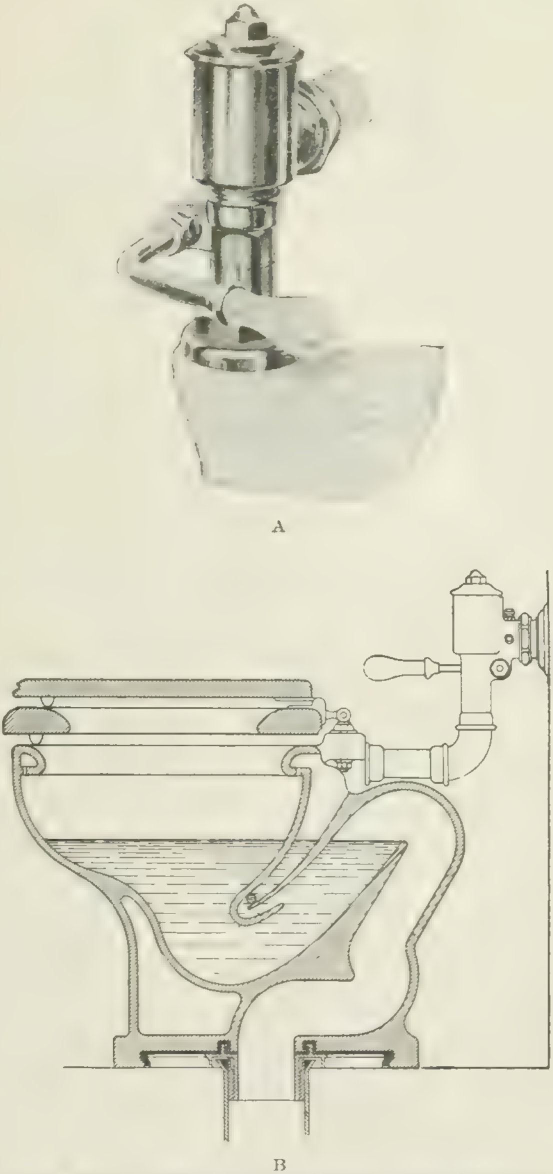


Fig. 44. Direct-Flushing Closet Dispensing with Necessity of Tank. *A* Shows Hand-Flushing Valve; *B* Complete Fixture with Sectional View of Siphon Closet.

Courtesy of the J. L. Mott Iron Works

The objections to the range type of fixture are inherent in the design. The fouling surface of a trough fixture is much greater than that of the number of individual closets to which the fixture corresponds, and certain parts of this surface are not subject to an adequate flushing action. A certain portion of the surface, much larger relatively than that in individual fixtures, is exposed to spattering with the filth, and is alternately wet and dry. It is also true that the method of applying the water for scouring purposes is much less satisfactory than with single closets. A further objection to the range fixture is that in general its material is less desirable for the purpose than the earthenware or porcelain used for closets. On account of these deficiencies, for some ten years past, individual closets have been used in public schools in certain cities which have given the most attention to this branch of sanitation, and their use is being extended.

Range closets have automatic flushing tanks acting at any required interval between flushes. The tanks are, as a rule, without moving parts, and give good service without much attention after the supply is once set to flush at the interval desired. Whether the users of a closet are indifferent or irresponsible, does not change the result of abuse; and the range type of closet overcomes many annoyances attending the use of ordinary individual closets in unsuitable places—institutions for the insane and feeble-minded, for example. Ranges, like seat-action closets, are not dependent on the user, who may forget to pull a chain or push a button and thereby leave the closet foul.

Various forms of ranges are now operated on the siphon eduction principle. Siphonic eduction is accomplished in three ways—first, by the double trap and air-pipe to the tank indicated by the sectional view, Fig. 45, and operating exactly like the individual pneumatic closet already described; second, by a siphon outlet-end in which the water falls over a central weir that maintains the proper depth of water until the flush begins, and causes siphonage by breaking up and filling the channel as it passes through a constricted bend below. The latter method is shown in section in Fig. 46. Still another type of range is made to siphon by jet-action, just as the individual jet-siphon closet does, the trap providing a retaining weir which holds the water at the proper level in the range between flushes.

There are wash-out ranges with sloping weirs at the outlet to retain enough water to keep soil from sticking. These are open troughs, and the plumber provides the trap. Some siphon ranges are of the open-trough pattern, but the trap or the siphon outlet is a part of the fixture. All open-trough ranges can be supplied with a ventilating section from which a large vent pipe may be carried to a stack in which a draft is insured by a hot flue or some other means. Such ventilation changes the air in the room; and by having lids to all the seats, odors from the entire trough may be uniformly removed by leaving up one lid only, at the end opposite the vent pipe. Some forms, having individual flushing-rim bowls cast integral with the section, are supplied by one general flush pipe, as indicated by the plan and elevation shown in Fig. 47. In these, each bowl is separately water-sealed, as the normal water-level is above the general conduit into which the bowls discharge.

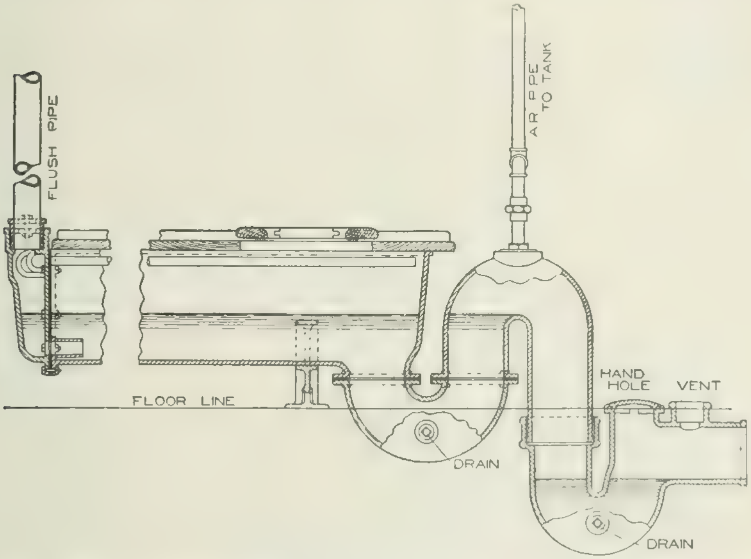


Fig. 45. Section of Range Closet, with Double Trap and with Air Pipe to Tank to Cause Siphonic Eduction.

Other forms, which receive the entire flush at one end, are water-sealed between the seat holes. The seat-openings, instead of converging like flushing-rim bowls, diverge downward, so that, as the water-level recedes in the sections during flushing, soil falls away from the surface by gravity instead of grinding against it. Therefore, so far as cleanliness is concerned, the type with diverging surfaces but without the scouring effect of flowing water in the openings is, in operation, the practical equivalent of the flushing-rim type with converging surfaces. The open-trough ranges, including the jet-siphon type, have perforated wash-down pipes along the sides and ends, which, however, have little value. The open troughs are made in cast sections as long as convenient, joined by flanges with rubber gaskets and bolts. Suitable feet or chairs for supports are furnished with these fixtures.

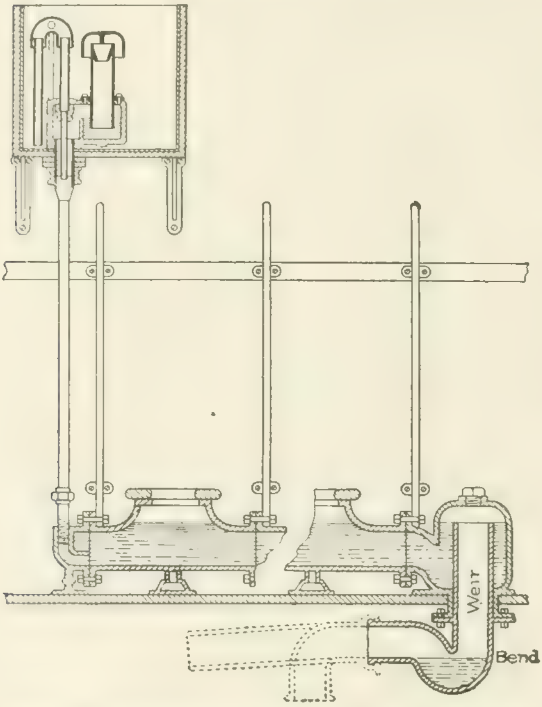


Fig. 16 Section of Range Closet, with Siphon-Outlet End.

Cast partitions, partitions and backs, and full compartment partitions, with slat doors and indicators, are furnished to order in any style or combination desired. For example, the range for a schoolroom may consist altogether of 24-inch sections or divisions, except one intended for the teachers' use made 30 inches and fitted with door and full-length partitions to give a thoroughly private compartment. Ranges are usually made of cast iron, and almost invariably finished with enameled interior and painted exterior. Bowl or section ventilation is provided for where possible. Wood seats and covers are generally used; but enameled-iron top frames with hinged seats and covers, and rigid enameled seats, are also made.

The lower trap of a double-trap range must be ventilated. All soil-pipe stacks into which ranges discharge, and fixtures connected to them, must be well protected against siphonage, because the volume of water discharged at one time by a range is sufficient to siphon traps that would retain their seals under most other conditions.

Urinals. Sectional urinals are made of the same materials and finish, and with much the same types of design, as range closets. They are generally installed in the same classes of buildings as range closets; but such urinals will often be found in the same toilet-room with individual closets. Roll-rim enameled troughs, with back and with simple perforated wash-down flush pipes on the back, are available.

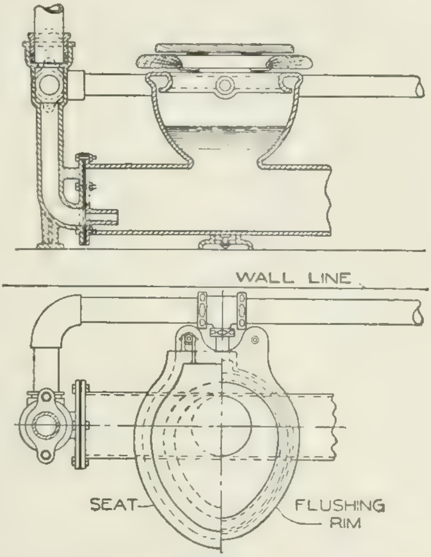


Fig. 47. Sectional Elevation and Plan of Range Closet Seat with Flushing-Rim Bowl Supplied from General Flush-Pipe.

Single urinals are usually of porcelain, although some have been made of iron. The common types are plain or lipped, made in flat-back and corner designs. Flat-back types of both designs are shown in Fig. 48. All have flushing rims. Direct-flushing valves of the same type as used on closets, adapted to the purpose,

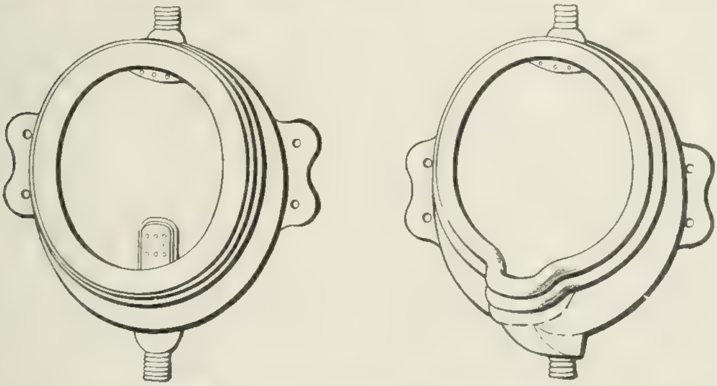


Fig. 48. Flat-Back Types of Single Urinals.

and cocks of various types, are the means of flushing generally provided for a single urinal. When two or more are placed in one toilet-room, an automatic tank with branched flush pipe is employed. These tanks are of greater variety than those used with range closets. The tilting bucket, pivoted within a tank case, which empties itself periodically by means of the flow of water changing the center of gravity to the unsupported side and tipping it just before it overflows, is a familiar type of automatic urinal-flushing tank. The standard tank with immovable parts, which siphons automatically, is also prevalent. Examples of these types are illustrated in section in Fig. 49.

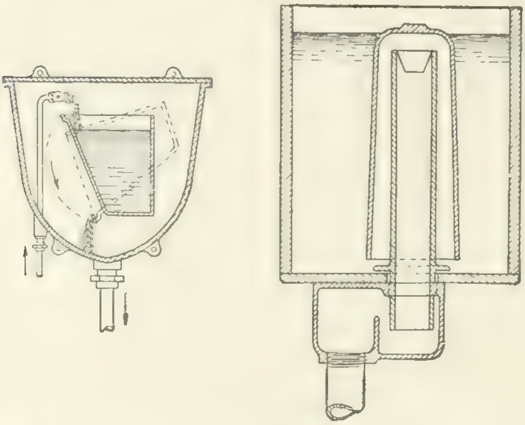


Fig. 49. Automatic Urinal-Flushing Tanks. Tilting-Bucket Type at Left; Self-Siphoning at Right.

Another design consists of a tank with common siphon, fitted with a ball cock which *opens*, instead of closing, as the water in the tank lifts the ball. The interval between flushes is governed by a small bibb cock, which may be turned on more or less so as to take greater or less length of time for the water in the tank to reach the ball. When water begins to lift the ball, the ball cock also admits water. From this point the tank fills

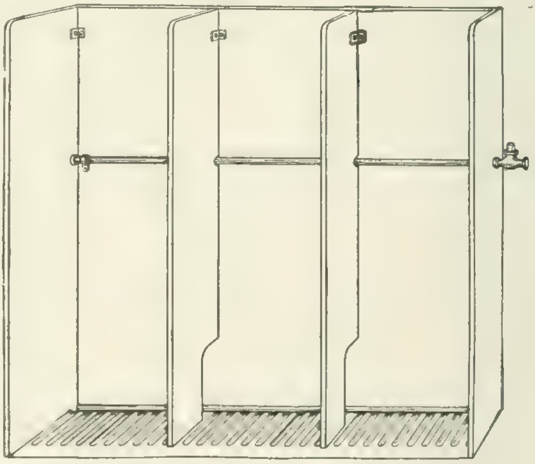


Fig. 50. Urinal Stalls of Slate or Marble, Flushed by Perforated Pipe, with Channeled and Guttered Floor.

rapidly. The higher the ball is lifted, the faster the tank fills, so that by the time the water-level reaches a point where water begins to flow over the neck of the siphon, it is coming into the tank rapidly enough to more than keep pace with the overflow necessary to start the siphon. True siphonage, however, empties the tank much faster than the supply can fill it; and the tank is soon empty, leaving the small bibb cock to admit water again slowly to where this action can be repeated.

Individual urinals which siphon by admitting additional water to that which normally stands in the fixture, and various other types, will be best understood from a study of dealers' catalogues. In good work, marble backs and partitions usually enclose the urinals on three sides. Marble and slate stalls of various construction, with channeled and guttered floor, as shown in Fig. 50, all washed by perforated pipes fixed along the surfaces, are frequently used in lieu of specific urinal fixtures. A thick base of slab material is sometimes used, the gutter and drain-hole being cut in it. Cast-iron gutters, galvanized or enameled, with an outlet-end adapted to a soil-pipe connection, are supplied by the makers.

In describing the fixtures and trimmings that have been noticed, only salient features of form and principles of design have been considered. Sufficient guidance to insure intelligent comparison of merits and skilful discrimination in selection, has been given. Catalogue detail and illustration, and a view of the actual goods described therein, should, with what has now been given, insure the fullest understanding of the fixture branch of Plumbing.

HOUSE WATER SUPPLY

While the plumber is apt to give more attention to supply pipe, and to methods of installing it in buildings to secure specific service, *water supply* embraces also, in its broadest sense, the source and quality of water and the means of conveying it to the building. Plumbers generally have little dealing with water supply outside of the house walls. Custom has fixed certain arbitrary sizes in ordinary work, to such a degree that the average plumber has generally ignored information on the flow of water through pipes. Indeed, he is so rarely in actual need of this knowledge, that it appears a burden to acquire and to fix permanently in his mind the simplest formula bearing on the subject. Enough information to determine approximate deliveries and point the road to further research, will not be out of place in behalf of those who may need simple directions.

The laws of gravity are the basis for the science of hydraulics, of which a prime factor of every problem is *velocity*. There is no exception to the rule that all bodies falling freely, descend at the same rate—in round numbers, 16 feet for the first second, at the end of which the acquired velocity is one of 32 feet a second. This is the basis on which are formulated the laws of falling bodies, which, exhibiting what is known as *velocity of efflux*, together with loss by friction, must be considered when calculating the flow of water.

There are three kinds of velocity—*uniform*, *accelerated*, and *retarded*. It is the last, and its cause, friction, that plumbers should be most interested in, as velocities calculated merely from the laws of falling bodies do not take account of friction, change of course, etc., which must be allowed for as causes diminishing the delivery of water through pipes. Briefly stated, the mysterious-looking Torricellian formula $\sqrt{2gh} = V$, means only that velocity is found by extracting the square root of the product of the head multiplied by 2×32, g standing for the force of gravity, and h for the height. For example, a stream filling a 1-inch pipe, with 25 feet head of water, would have a velocity calculated thus: $2 \times 32 \times 25 = 1{,}600$; and the square root of $1{,}600 = 40 =$ Velocity, friction not considered.

The shape of the orifice through which water enters a pipe, has much to do with the amount of water that will enter it. Friction against the sides of the pipe, and change of direction due to bends and connections, occasion great variation from the theoretical flow. Not only is the character of the pipe surface and fittings to be considered as initial causes varying the delivery, but velocity, the all-important factor, must be reckoned with in every instance. With a velocity of 10 feet per second in a pipe of comparatively smooth interior surface, the friction loss in pounds on one square foot of surface will be about ½ pound. If this velocity is increased or diminished, the factor of friction will vary accordingly, always in proportion to the square of the velocity. Suppose the velocity to be 20 feet instead of 10 feet per second; we then have, 10 squared equals 100, and 20 squared equals 400. The square of these velocities is as 1 to 4, and as we assign a ½-pound loss to ten feet velocity per second, on a stated amount of surface, the friction due to doubling the velocity should be four times a $\frac{1}{2}$ pound = 2 pounds, showing that doubling the velocity increases the friction four-fold; trebling it increases friction nine-fold, etc.

A column of water weighs .43 pound per square inch of base, per vertical foot. Therefore a vertical pipe 100 feet high, with 1-inch sectional area, filled with water, would contain 43 pounds, and a gauge at the bottom would show 43 pounds pressure. If the pipe were only $\frac{1}{4}$ inch, or were 40 inches in diameter, the gauge would show the same pressure for the same vertical height—namely, .43 pound per square inch per vertical foot. A head of water expressed in feet, may be changed to pounds by multiplying the feet of head by .43. Pressure is made to read in feet of head by multiplying pressure per square inch by 2.3. A *head of water* is the number of vertical feet from level of source of supply to center of outlet or point of delivery.

Diameter of the pipe has nothing to do with static head or pressure; but its relation to the size of the orifice from which the water is to be drawn has much to do with the amount of pressure lost by friction. If a faucet and supply pipe are of the same size, and we *double* the size of the pipe, the velocity of the water flowing through it is reduced three-fourths; and the friction is, under these conditions, but one-sixteenth what it was in the original size. Moreover, as in drawing similar amounts of water under the same head through a one-inch and a two-inch pipe, the amount of friction surface presented is twice as great in the one-inch as in the two-inch pipe, the friction in the one-inch can be shown to be 32 times as much as in the two-inch pipe.

With the formula given, one can roughly approximate by finding the theoretical delivery and deducting a liberal percentage for friction, according to size, length of pipe, and head or pressure. The subject, however, is vast and tedious, introducing intricate calculations in higher mathematics when considered in detail with a view to extreme accuracy of results, and is a branch properly belonging to hydrodynamics, rather than suited to presentation at length here. Two tables are given, however, which with the rules for use, will be of value to those who fail to make further research.

Table I shows the pressure of water in pounds per square inch for elevations varying in height from 1 to 135 feet.

Table II gives the drop in pressure due to friction in pipes of different diameters for varying rates of flow. The figures given

TABLE I

Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch
1	.43	46	19.92	91	39.42
2	.86	47	20.35	92	39.85
3	1.30	48	20.79	93	40.28
4	1.73	49	21.22	94	40.72
5	2.16	50	21 65	95	41.15
6	2.59	51	22.09	96	41.58
7	3.03	52	22.52	97	42.01
8	3.46	53	22.95	98	42.45
9	3.89	54	23.39	99	42.88
10	4 33	55	23.82	100	43.31
11	4.76	56	24.26	101	43.75
12	5.20	57	24.69	102	44.18
13	5.63	58	25.12	103	44.61
14	6.06	59	25.55	104	45.05
15	6.49	60	25.99	105	45.48
16	6.92	61	26.42	106	45.91
17	7.36	62	26.85	107	46.34
18	7.79	63	27.29	108	46.78
19	8.22	64	27.72	109	47.21
20	8.66	65	28.15	110	47.64
21	9.09	66	28.58	111	48.08
22	9.53	67	29.02	112	48.51
23	9.96	68	29.45	113	48.94
24	10.39	69	29.88	114	49.38
25	10.82	70	30.32	115	49.81
26	11.26	71	30.75	116	50.24
27	11.69	72	31.18	117	50.68
28	12.12	73	31.62	118	51.11
29	12.55	74	32.05	119	51.54
30	12.99	75	32.48	120	51.98
31	13.42	76	32.92	121	52.41
32	13.86	77	33.35	122	52.84
33	14.29	78	33.78	123	53.28
34	14.72	79	34.21	124	53.71
35	15.16	80	34.65	125	54.15
36	15.59	81	35.08	126	54.58
37	16.02	82	35.52	127	55.01
38	16.45	83	35.95	128	55.44
39	16.89	84	36.39	129	55.88
40	17.32	85	36.82	130	56.31
41	17.75	86	37.25	131	56.74
42	18.19	87	37.68	132	57.18
43	18.62	88	38.12	133	57.61
44	19.05	89	38.55	134	58.04
45	19.49	90	38.98	135	58.48

are for pipes 100 feet in height. The frictional resistance in smooth pipes having a constant flow of water through them is proportional to the length of pipe. That is, if the friction causes a drop in pressure of 4.07 pounds per square inch in a 1¼-inch pipe 100 feet long, which is discharging 20 gallons per minute, it will cause a drop of 4.07 × 2 = 8.14 pounds in a pipe 200 feet long; or 4.07 ÷ 2 = 2.03 pounds in a pipe 50 feet long, acting under the same conditions. The factors given in the table are for pipes of smooth interior, like lead, brass, or wrought iron.

TABLE II.

	½ in.		¾ in.		1 in.		1¼ in.		1½ in.		2 in.		2½ in.		3 in.	
Gallons discharged per minute.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.
5	8.17	24.6	3.63	3.3	2.04	.84	1.31	.31	.91	.12						
10	16.3	96.0	7.25	13.0	4.08	3.16	2.61	1.05	1.82	.47	1.02	.12				
15			10.9	28.7	6.13	6.98	3.92	2.38	2.73	.97	1.53	.27				
20			14.5	50.4	8.17	12.3	5.22	4.07	3.63	1.66	2.04	.42				
25			18.1	78.0	10.2	19.0	6.53	6.40	4.54	2.62	2.55	.67	1.63	.21	1.13	.10
30					12.3	27.5	7.84	9.15	5.45	3.75	3.06	.91				
35					14.3	37.0	9.11	12.04	6.36	5.05	3.57	1.25				
40					16.3	48.0	10.4	16.10	7.26	6.52	4.09	1.60				
45							11.7	20.2	8.17	8.15	4.60	2.02				
50							13.1	24.9	9.08	10.0	5.11	2.44	3.26	.81	2.27	.35
75							19.6	56.1	13.6	22.4	7.66	5.32	4.90	1.80	3.40	.74
100									18.2	39.0	10.2	9.16	6.53	3.20	4.51	1.31
125											12.3	14.9	8.16	4.89	5.67	1.99
150											15.3	21.2	9.80	7.00	6.81	2.85
175											17.1	28.1	11.4	9.46	7.91	3.85
200											20.4	37.5	13.1	12.47	9.68	5.02

Examples.—A 1½-inch pipe 100 feet long connected with a cistern is to discharge 35 gallons per minute. At what elevation above the end of the pipe must the surface of the water in the cistern be to produce this flow?

In Table II we find the friction loss for a 1½-inch pipe discharging 35 gallons per minute to be 5.05 pounds. In Table I we find a pressure of 5.2 pounds corresponds to a head of 12 feet, which is approximately the elevation required.

How many gallons will be discharged through a 2-inch pipe 100 feet long where the inlet is 22 feet above the outlet? In Table I we find a head of 22 feet corresponds to a pressure of 9.53 pounds. Then, looking in Table II, we find in the column of Friction Loss for a 2-inch pipe that a pressure of 9.46 corresponds to a discharge of 100 gallons per minute.

Tables I and II are commonly used together in examples.

A house requiring a maximum of 10 gallons of water per minute is to be supplied from a spring which is located 600 feet distant, and at an elevation of 50 feet above the point of discharge. What size of pipe will be required? From Table I we find an elevation or head of 50 feet will produce a pressure of 21.65 pounds per square inch. Then if the length of the pipe were only 100 feet, we should have a pressure of 21.65 pounds available to overcome the friction in the pipe, and could follow along the line corresponding to 10 gallons in Table II until we came to the friction loss corresponding most nearly to 21.65, and take the size of pipe corresponding. But as the length of the pipe is 600 feet, the friction loss will be six times that given in Table II for given sizes of pipe and rates of flow; hence we must divide 21.65 by 6 to obtain the available head to overcome friction, and look for this quantity in the table, $21.65 \div 6 = 3.61$, and Table II shows us that a 1-inch pipe will discharge 10 gallons per minute with a friction loss of 3.16 pounds, and this is the size we should use.

In calculating the contents of pipes, cylinders, and cisterns, where it is usual to correct the area found as a result of squaring the diameter by multiplying by .7854, before dividing by 231 for U. S. gallons, multiplication by the decimal may be omitted, and dividing by 294 instead of 231 will then give the same result.

EXAMPLES FOR PRACTICE

1. What size pipe will be required to discharge 40 gallons per minute, a distance of 50 feet, with a pressure head of 19 feet?

Ans. 1¼-inch.

2. What head will be required to discharge 100 gallons per minute through a 2½-inch pipe 700 feet long?

Ans. 52 feet.

TYPES OF WATER SUPPLY

There are various ways in which it may be necessary to obtain the water supply for a building. The usual course in cities and towns is to employ the Municipal Water Works service. This, of course, settles the supply feature, and the plumber simply provides the house and yard pipe, ¾-inch or larger main, according to the character of the work. If of lead, the pipe must be of strength according with the pressure. Any of the light-weight grades of lead supply will stand 1,000 pounds per square inch for a short time; and the usual strength used on 50 to 80-pound pipe will not burst under 1,400 to 1,600 pounds when new and unstrained. Under constant pressure, the enormous strain possible from water-hammer, and general deterioration from use, make it advisable to employ pipe which, when new, is 20 times as strong as that necessary to contain the pressure. No attention is necessary as to the strength of zinc-coated or tin-coated iron pipe; it will stand any pressure ordinarily encountered.

The two general methods of supplying buildings with water are: (1) the *direct* system; and (2) the *indirect* or *tank* system. The direct method, generally employed in cities, places each fixture connected with the supply under the same pressure as the street main, unless a reducing valve is introduced, thus often subjecting the work to needless high pressure and always to the widely varying conditions and quality of service incidental to such use. In the direct system it is good practice, where at all practicable, to pipe and fit the work generally for pressure not exceeding 50 pounds per square inch, and then use a reducing valve to maintain such pressure as is required.

The indirect method is almost always necessarily employed in isolated work; and even where municipal service is available, it is generally better for ordinary domestic purposes. With the indirect system, the connection with the street main is carried directly to a tank placed in the attic, or at some point above the highest fixture, as shown in Fig. 51. The supply to tank is regulated by a ball-cock which automatically shuts off the water when the tank becomes full and opens and refills it again when water is drawn out. All the plumbing fixtures are supplied directly from the tank, and are therefore under a constant minimum pressure depending on the distance the fixtures are situated below the tank. The tank storage is a matter of great convenience during repairs to street mains, aside from its advantages of uniform pressure, reduced expense of fitting and maintaining low-pressure work, etc.

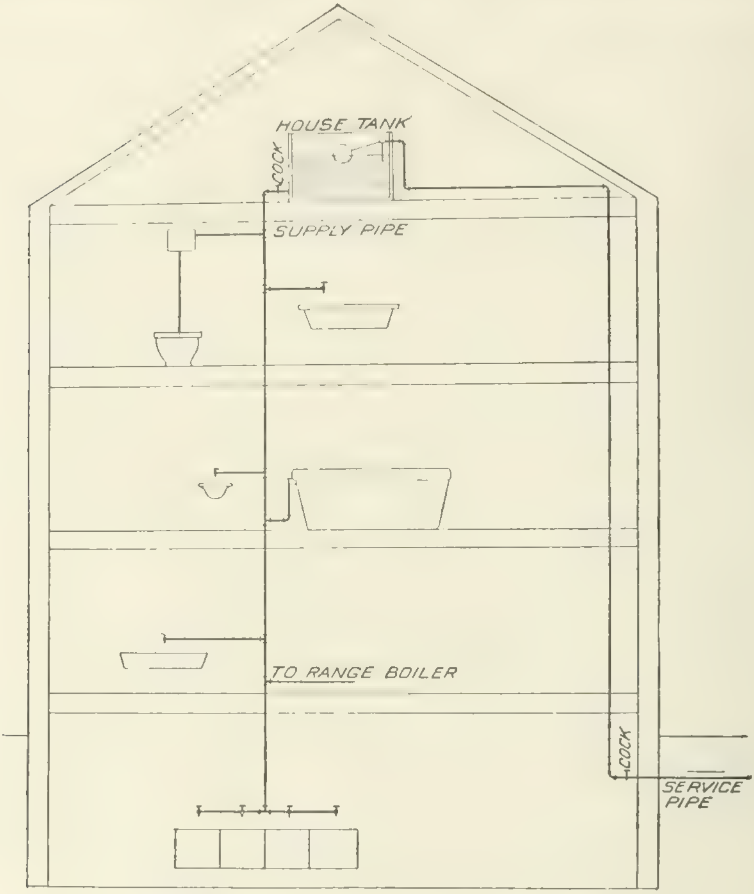


Fig. 51. Indirect or Tank System of House Supply.

In municipalities where the pressure in the main is not sufficient to carry the water up to the house tank in the attic, and in elevated situations, an automatic, electrically-operated rotary or other suitable form of pump is often installed to lift the water. A screw pump like that shown in Fig. 52 is especially adapted to this use when equipped with an electric motor to start and stop automatically by means of a float in the tank operating an electric switch as shown in the engraving.

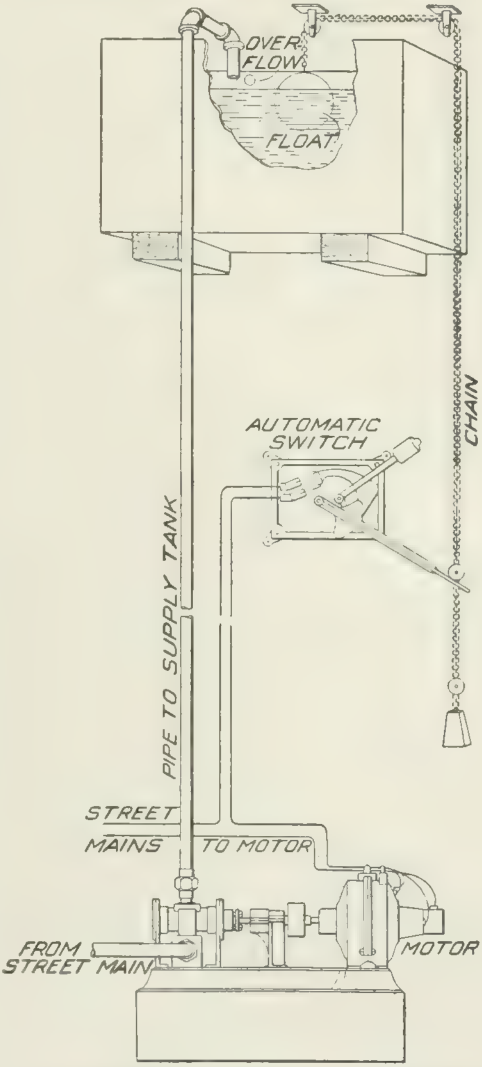


Fig. 52. Electrically-Operated Pump for Lifting Water to Tank. Automatically Started and Stopped by Means of Float Operating Electric Switch.

Where steam pressure is available, steam-operated pumps are very frequently used, and are invariably arranged for automatic service whether there are engineers regularly in attendance or not. A device that may be attached to steam pumps for this purpose is shown in Fig. 53. When the high-water line in the tank is reached, the float closes a valve in the pump discharge pipe, thus promptly increasing the pressure in it so as to actuate a piston through a pipe connection from the pump discharge to the regulator beneath the piston head. The regulator is shown complete, in detail, partly in section, in Fig. 54. Raising the piston shuts off the steam supply to the pump at the governor valve. When the water line in the tank is lowered, the float falls and the ball valve opens, relieving the pressure in the pump discharge pipe and allowing the steam governor valve to open by the action of the coun-

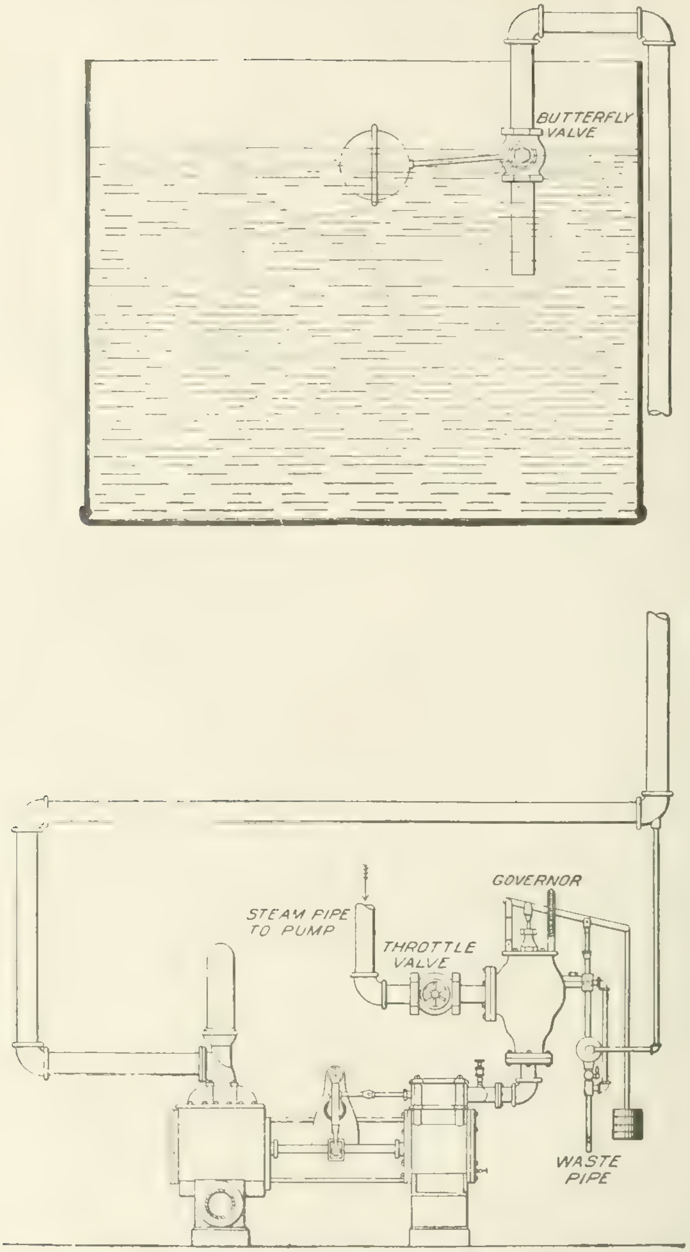
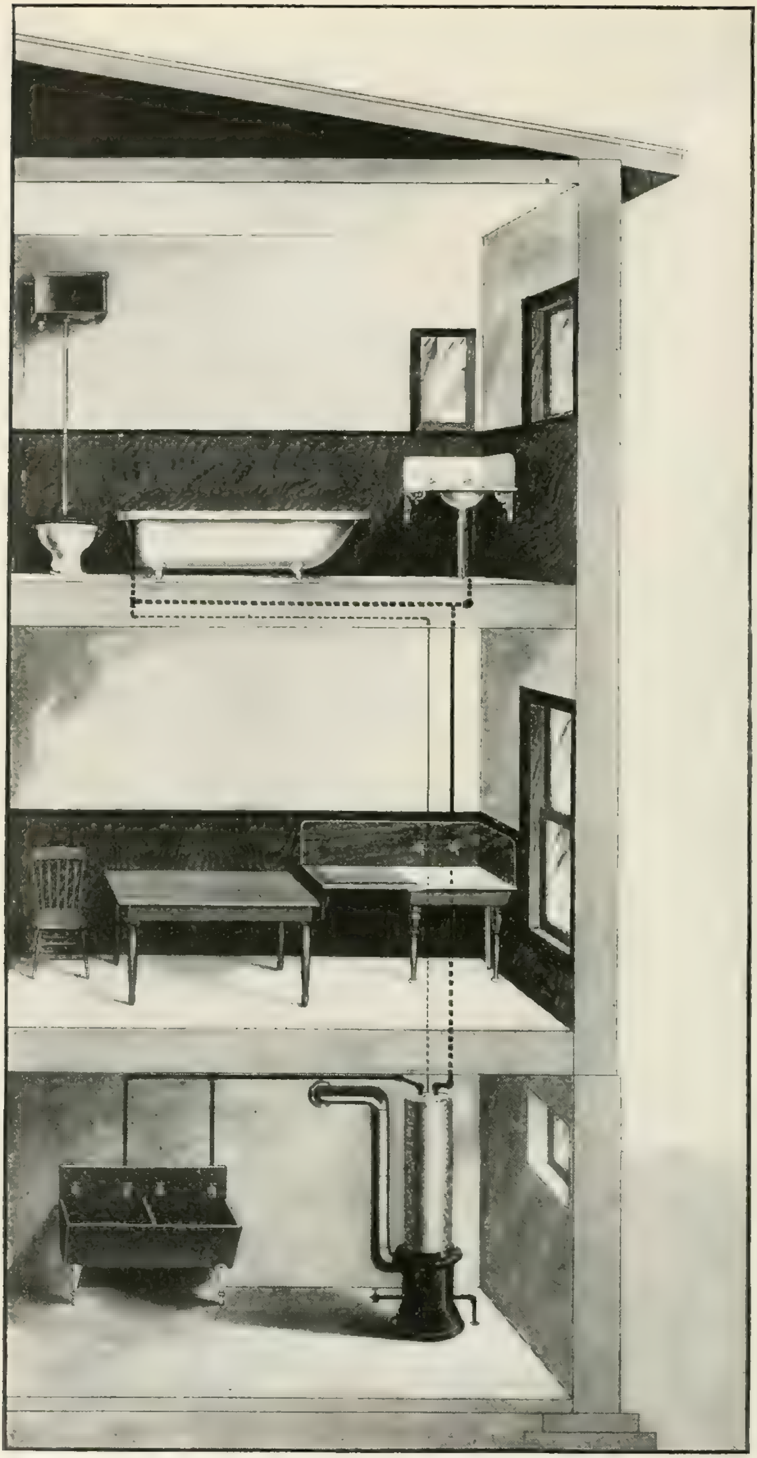


Fig. 53. Steam Pump Equipped with Regulator Operated by Float in Tank, Securing Automatic Service.



SECTION THROUGH BATH-ROOM, KITCHEN, AND BASEMENT, SHOWING METHOD OF INSTALLING WATER HEATER

The Heater Proper and Tank or Range Boiler are Combined, and Can be Placed either in Kitchen or Laundry
James B. Clow & Sons, Chicago

terweights attached to the lever arm, as shown; and the pump then works regularly until the lifting of the float by the rising water again closes the valve in the pump discharge and repeats the action described.

Outside of corporations, the supply may be from an elevated spring or stream, or from wells, cisterns, or other sources below the level of use. If the natural supply is high enough, it may be conveyed into a tank of sufficient height without intermediate apparatus. Tanks inside the dwelling or house are best, ordinarily.

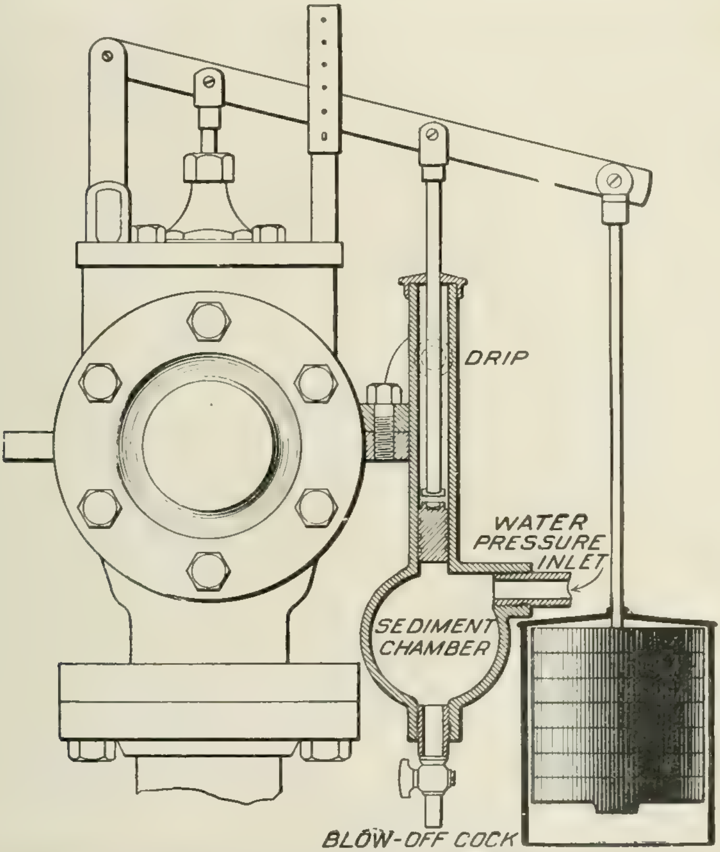


Fig. 54. Steam Pump Regulator (Shown Partly in Section) Automatically Operated by Valve Controlled by Float in Supply Tank.

Tanks for cold-water storage are made of various materials and in different shapes and sizes, according to the special uses for which they are required. For indoor use, copper-lined or lead-lined wood-case tanks without safe-pans, and wrought-iron or cast-iron tanks with safe-pans to catch the condensation, constitute the list generally favored by reason of superior fitness. Within limited dimensions, a durable and satisfactory tank-case can be made of heavy, well-fitted, and well-seasoned plank bolted together with iron rods and nuts, as shown in Fig. 55. For large sizes, heavy wood stays with tie-rods one-third of the way from each end, are added. With copper linings, but few nails should be used; and they should be so placed as to be covered by the copper, the joints being soldered by soaking the best quality of solder into the seams. The locking of the seams is shown greatly exaggerated in the engraving.

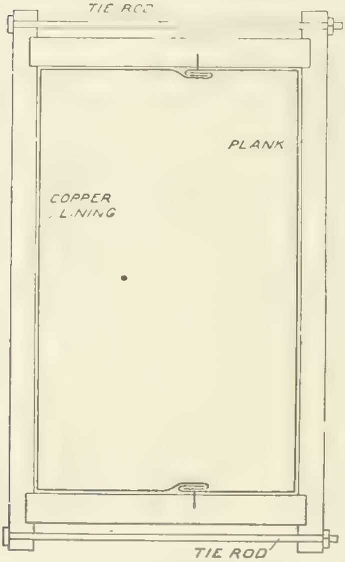


Fig. 55. Plan of Storage Tank in Case Made of Planks Bolted Together.

Cast-iron sectional tanks, like the form shown in Fig. 56, can be had in almost any size or shape. They are made up of plates planed and bolted together, the joints being made water-tight with cement. The sections are in convenient sizes, so that they can be handled

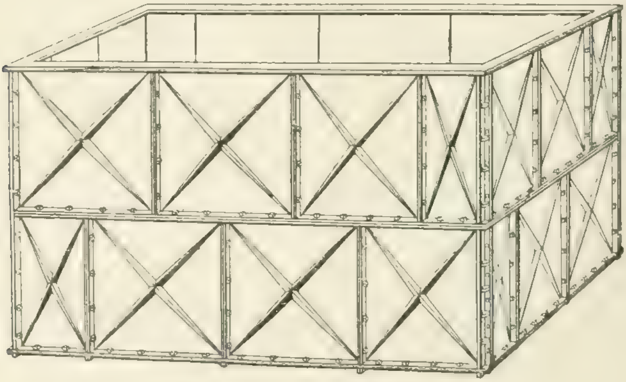


Fig. 56. Cast-Iron Sectional Tank.

easily, and conveyed without difficulty through small doorways or other openings to any part of the house. These tanks are easily set up, and are practically indestructible. Open and closed wrought-iron tanks, plain or galvanized, are often used, but are not so easily handled; and the larger sizes require to be riveted together and calked in place.

Lead-lined tanks are most frequently used for ordinary house plumbing. The linings were formerly wiped-in without exception. Sweating the lead together with a torch flame is however, quite as durable, and is much cheaper. To *sweat-in* a lining, take the exact length and breadth of the tank, trying at different points to be sure of allowing for any variations. Then cut out the bottom lining just the shape of the tank bottom, one and one-half inches larger each way, less twice the thickness of the lead. This allows three-quarters of an inch to turn up all around; and the bottom will just fit when the side pieces are in place. Mark off the bottom all around, as shown by the dotted lines in Fig. 57; and turn up the edge. With the intersection of the lines A as a center, and the termination of one of them as a starting point, describe the line B, and cut off the corner outside of it. Then *work* the corner up square without a kink. If the lead is heavy, a little heat will make it work better. After working-up, the lead at the corners will be much thicker than along the sides; this may be needed in stretching out, at some of the corners.

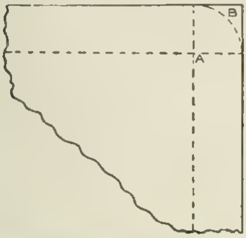


Fig. 57. Marking Off Bottom Sheet of Lead for Tank Lining, Leaving Edge to be Turned Up.

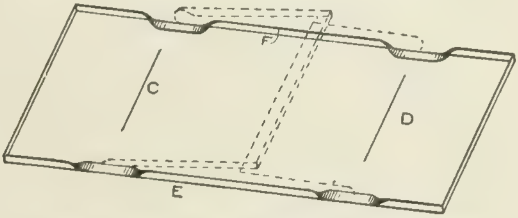


Fig. 58. Bending Bottom Sheet of Lead Ready to be Put in Tank.

When the edges and corners of the bottom are formed, clean the edges and about three-eighths of an inch down the outside all around, and rub the clean part with sperm candle. Next make a mark, say three feet from one end on each side, as at E and F, Fig 58. Then, on lines C and D, push the edges down inside, and fold the ends over as indicated by the dotted lines.

The bottom is now ready to be put in the tank, but it must wait until the sides and ends are in. If the sides and ends are light enough to be handled after joining like a ring, cut out a strip half an inch longer than will exactly go around the tank inside, equal to its depth plus the thickness of the tank wood for a flange at the top, as shown at J, Fig. 63. Then clean a half-inch of the under side and edge of the end that is to show in the seam, and three-quarters of an inch of the side that comes in contact with it, at the other end. The lead may then be propped up in the position shown in Fig. 59, by means of trestles and poles or in any other convenient manner; and the seam may be set, as shown, upon a board of hardwood, and the solder sweated into the lap by means of the torch and blowpipe. Solder for this kind of work should be three-fifths tin and two-fifths lead. A hardwood board is used because it will not smoke and burn like soft wood.

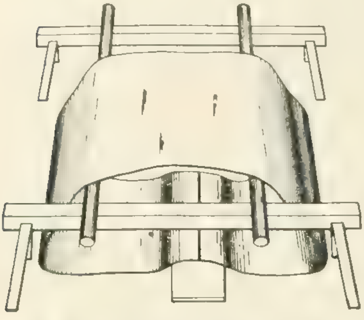


Fig. 59. Side and End Sheet of Lead Propped Up to Enable Seam to be Set and Soldered.

When the seam is made in this way, it shows inside the tank, and a good joint where the bottom seam crosses it can be made with ease, while one is never quite sure of the result if the seam crossed is on the other side.

Another method is to cut the lead the exact length that will go around the tank, clean the edges, butt them together over a hardwood board, as shown in Fig. 60, and *burn* them together instead of soldering. This can be done by using, instead of solder, a well-cleaned strip of lead about half an inch wide. Sperm candle will also answer as flux for burning. A piece of steel

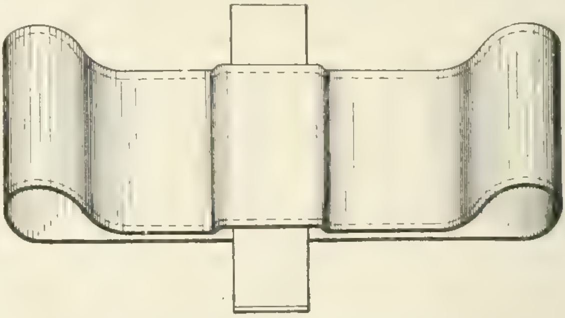


Fig. 60. Another Method of Joining the Two Ends of the Lead Sheet. The Ends are Butted against Each other Over the Hardwood Board and Fused Together.

or iron is best to place under the seam when burning, as more heat is required to do the work. An old crosscut saw blade, fastened to a board, serves well for such seams. The bottom edge of the side lining should be cleaned 1¼-inches wide, as shown at *H*, Fig. 61, which indicates how the cleanings on the bottom and the side and end lining come together in the tank. It is a good plan to run the soil brush around the bottom edge of the lining, as shown at *O* and *P*, Fig. 61. The soil keeps the solder from sweating too deep, and enables the seam to fill quickly. Further than this, however, soiling, as in the preparation for wiping, is not necessary for sweated seams.

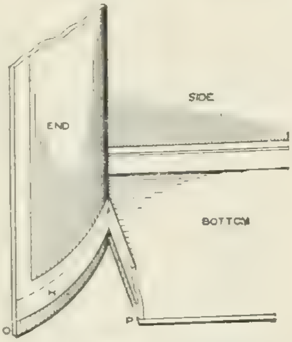


Fig. 61 Method of Joining End and Side Linings to Bottom Lining

When the side lining "loop" is ready, lift it into the tank, square it out, flange over at the top, and secure the flange with brass, copper, or galvanized nails. Next, mark distances in the tank corresponding to those at *E* and *F* in Fig. 58. Then catch the bottom at the folded edges (Fig. 58), and lower it into the tank. As the ends are folded, there is room to stand inside the tank at the ends. Pull the folds upright so that marks *E* and *F* can be seen, and slide the bottom back or forward until *E* and *F* correspond with the marks made on the side lining. The ends may then be pushed down in place, and will be found to fit exactly if the measures have been properly taken.

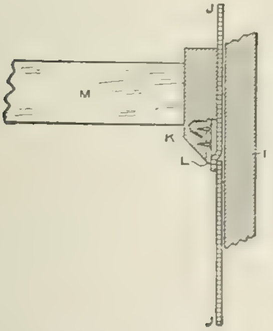


Fig. 62 Method of Keeping Lead in Place While Making Upright Seam in Tank.

After dressing down the bottom and pressing the turned-up edges against the sides and ends, sweat the bottom to the sides in the same way as the other seam was made, being sure that the solder "takes" well to both pieces of lead.

When a tank is large, handle the sides and ends in two or more pieces, always having the seams that are to be made in place come at the ends of the tank, as the ends are stiffest and best to brace against.

Fig. 62 shows the method of keeping the lead in place while making the upright seam in the tank, *I* being the tank wood, *JJ* the lining, *K* the straight edge, and *M* the brace. *K* is a piece of hardwood fastened to a strip of steel (a piece of an old framing square), as shown in the cut, the wood being about four inches wide by two feet long, and the steel *L* sticking half an inch out from the beveled edge of the wood. This steel edge keeps the lead from buckling under influence of the flame while blowing the seam, and is much better than a wood straight-edge, as it can be applied at the proper place with no fear of its burning or annoying the operator by smoking from the heat.

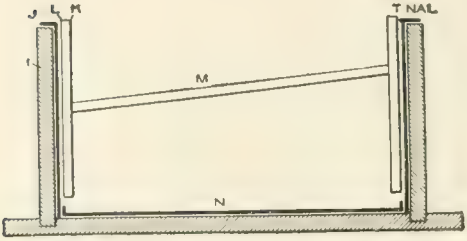


Fig. 63. Section Showing Lead Lining in Place and Method of Bracing for Making Upright Seams.

Fig. 63 shows the lining in place, and the method of applying the brace and straight-edge to the seams that are to be blown upright in position. Letters and parts in Figs. 62 and 63 correspond, *N* in Fig. 63 being the bottom.

Unless the supply is regular and abundant, and the storage by gravity, outside tanks of ordinary capacity, if of wood, are expensive and troublesome from leakage due to shrinkage of staves above the water-line and from necessity of painting; if of iron, from change in character of water, freezing, cost of boxing, delivery to, and discharge from, in a frost-proof manner, etc.

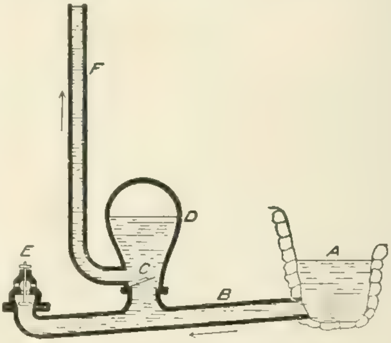


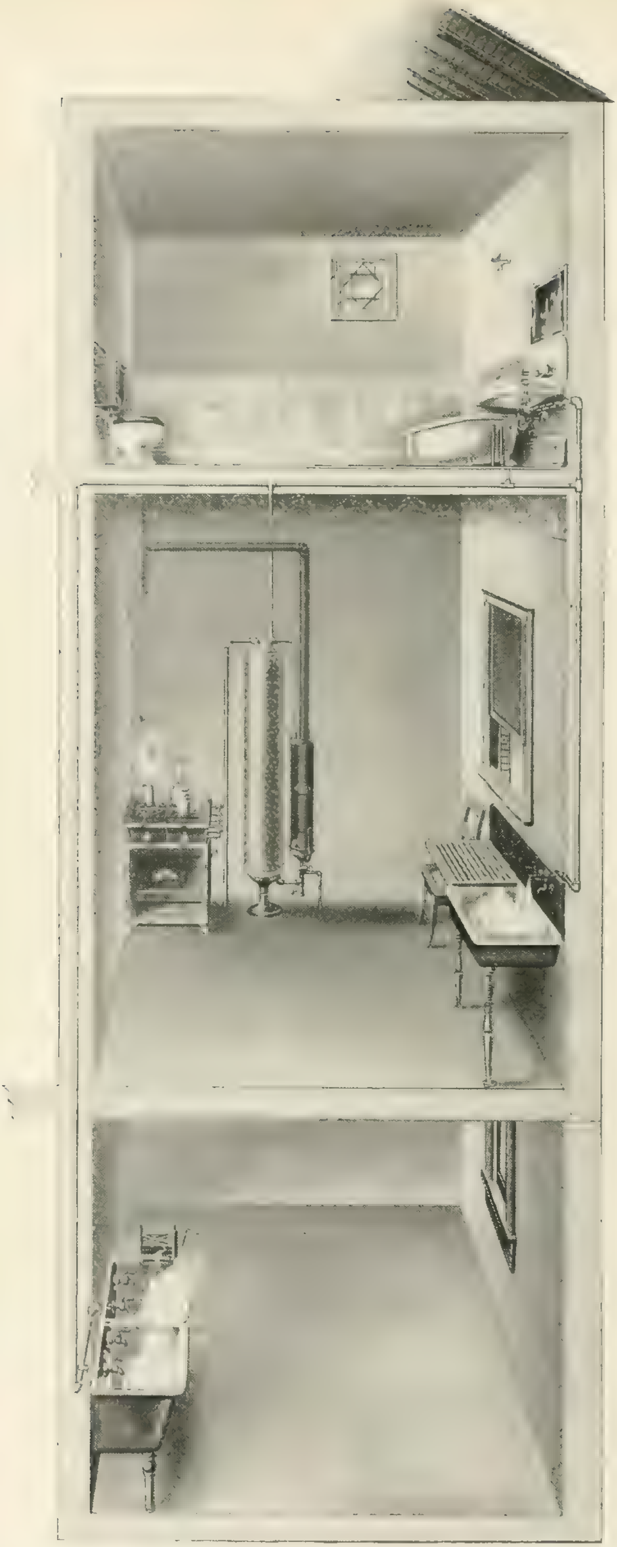
Fig. 64. Illustrating Principles of the Hydraulic Ram.

A spring supply will answer if of sufficient elevation to store water by gravity; or a waterfall above or below the house level may be handled with a hydraulic ram if 5 to 15 per cent of the water regularly available will suffice.

Hydraulic Ram. A ram uses the energy of a fall to elevate part of the water passing through it—one-sixth or less, according to the fall and the height to which the water is to be delivered. Four feet of fall is about as little as can be utilized to advantage; and fifty feet of liberal-size drive-pipe, even though it has to be coiled with uniform fall, is necessary to give the water momentum enough to get the best results.

Fig. 64 illustrates the elementary principles of a simple ram. *A* represents the source or spring; *B*, the drive (supply) pipe; *C*, a valve opening upward; *D*, an air-chamber; *E*, a valve tending to close downward by gravity; and *F*, the discharge pipe. In action, the water passes through the ram and out at a waste valve *E*, which is open downward until sufficient velocity is attained to lift and close the waste exit. There being then no other means of egress, the check-valve *C*, opening upward to the discharge pipe, is forced open; and the energy of acquired momentum delivers water into the air-chamber *D* and discharge pipe *F*, until the pressure on the waste valve falls too low to hold it up (closed). The check-valve *C* then closes, and retains the water in the discharge; and the waste valve *E* falls open by gravity, leaving a comparatively unrestricted exit through which the water continues to waste with increasing force until the velocity in the drive pipe is again sufficient to repeat the impulsive delivery. Rams are made with large air-chambers, to cushion the initial strain of impulse, and should have a delivery pipe at least one size larger than the ram opening, especially if working under light fall or high delivery.

Cisterns are seldom so deep or situated so low that ordinary house force-pumps within doors cannot be used. The distance of the cylinder above the lowest level from which water may need to be pumped, is limited in all pumps alike—33 feet 9 inches atmospheric lift under *perfect* conditions, and about 25 feet under the most perfect practicable pump arrangement. Indeed, the velocity of flow into the cylinder at any point above 20 feet is so slow that in practice the cylinder should be well within a twenty-foot limit in vertical distance from the water; and the closer the better. A foot-valve strainer at the end of a cistern suction pipe will keep the pipe filled and avoid frequent exhausting of the air before water can be obtained. When a foot valve is used, means of draining the suction to below frost line, when necessary, must be provided.



INTERIOR OF BATH-ROOM, KITCHEN AND LAUNDRY SHOWING INSTALLATION OF GAS WATER HEATER

James B. Clow & Sons, Chicago

PLUMBING

PART II

PUMPS

A common *suction pump*, shown in Fig. 65, is the type generally used in cisterns or other very short lifts. *B* is the plunger; *C*, the bottom valve; and *D*, the plunger valve. When the plunger is drawn up, a vacuum is formed in the cylinder, and water flows in through *C* to fill it. When the plunger is forced down, valve *D* opens and allows the water to flow through the plunger while *C* remains closed. Water is thus raised by the plunger at each stroke and flows from the spout in an intermittent stream. The atmospheric limit is indicated in the engraving; but, as before stated, the practical lift is taken at 20 feet or less in pumps having the plunger valve at the ground level. The plunger in this kind of pump is made to trip the bottom valve and drain the pump at will, without a waste-hole or special cock, by merely lifting the handle as high as possible.

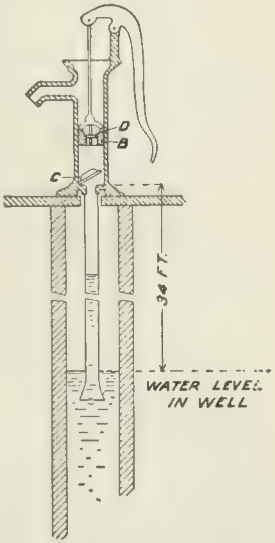


Fig. 65. Common Type of Suction Pump for Short Lifts.

When the surface of the water is a greater distance below the pump stock than ordinary suction can reach effectively, the cylinder and its working parts must be placed within the limits of lift by suction. This form is termed a *lift pump*, one type of which is shown in Fig. 66. This particular form is confined to ordinary open shallow wells or deep cisterns. It drains automatically through a waste-hole always open below frost line, located in the stock above the working barrel. There is no limit except the strength of the parts, to which a good lift pump will not bring water if the cylinder is near enough to the water and the pump in good order.

The forcing feature of a pump, making it a *lift and force pump*, is secured by working the rod of an ordinary lift pump through a stuffing box, and adding an air-chamber to take care of the surplus water pumped on the up-stroke and to expel it while the plunger is being lowered. All the water is pumped on the up-stroke of the plunger, in these pumps; and the expulsion of the surplus through the constricted spout, giving the familiar steady stream, is due to the action of the air compressed in the chamber.

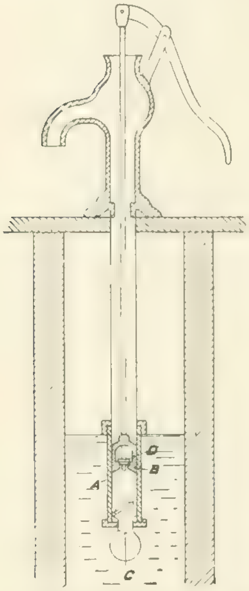


Fig. 66. Type of Lift Pump Adapted to Long Lifts.

Double-acting lift and force pumps draw water by suction on both strokes, and actually expel it by force into the discharge, the suction and force being alternate in the same cylinder on both sides of a solid plunger. The air-chamber in these cushions the delivery.

It may be stated here that hot water cannot be lifted by suction, because the boiling point of water depends upon the pressure on it. Therefore, any endeavor to create a vacuum with a pump results in vapor rising so freely as to prevent accomplishing appreciable results. Warm water can be forced by having the pump below the source, and practically allowing the water to flow into the pump by gravity.

In wells, whether driven, tubular, or open, it is advisable to have the cylinder very near the bottom. The pump standard, for hand use, should be strong, well-made, of 10-inch stroke, with rocking fulcrum, and with rod guided in perfect alignment; the handle leverage at least 6 to 1; lift pipe not less than 2 inches; rod, hollow, galvanized or wood; cylinder, at least twice the length of stroke, brass-lined, and not larger in diameter than the lift pipe—the whole being such that all valves can be withdrawn through the pipe and standard for repair or renewal without disturbing either standard body or pipe. A drain valve to empty standard and pipe below freezing point, is essential. A pump outfit of this character, to deliver water at the ground level, will require at the handle grip, 6 to 8 pounds force on

40-foot, 10 to 12 pounds on 50-foot, and 14 to 16 pounds on 60-foot wells. The lift pipe (above cylinder) should not be plain iron pipe. Polished iron cylinders ought not to be used, even though they are to be always submerged; incrustation will make it difficult to withdraw the cup-leathers—to say nothing of other objections.

The trouble with cylinders of larger diameter than the lift pipe, is the time and expense of withdrawing pipe and standard for repairs; and, of course, the power to pump with them equals the total lift *multiplied by* the sectional area of the cylinder in inches.

The importance of cylinder diameter will be better understood by comparison. A total lift of 100 feet, with cylinder 2 inches in diameter, gives 135 pounds, which, with the handle leverage at 6 to 1, will be lifted with from 22 to 25 pounds' force according to kind of rod, tightness of stuffing box, size of lift pipe, etc. With the same outfit and conditions, merely substitute a cylinder of 4 inches' diameter, and 540 pounds will then require to be lifted, which, with the same ratio of leverage, calls for over 90 pounds' force on the handle to lift the water. Then, if the lift pipe is materially smaller than the cylinder, the increase in velocity, when the cylinder water enters the lift pipe calls for an additional force that would astonish one. This should make it plain why so many pump standards are wrecked, bolts worn off, holes worn oblong, handles broken, cylinders continually needing new valves, and owners disgusted; it is all due to the lack of proper proportion of parts, and the enormous amount of needless work thus occasioned.

Total lift is the distance from the level of the source pumped from, to the point of discharge. This includes height to elevated tank, if there be one, and the distance from cylinder to water, if the cylinder is above the water; yet many mechanics are inclined to ignore the latter on the ground that the atmosphere lifts the water to the cylinder. It does, in fact; but the power of the vacuum which permits the atmosphere to lift the water, is as great as the weight of water so lifted, and the vacuum itself is produced and maintained by the energy of the person pumping.

The pump being outside for the purpose of sprinkling, filling vessels, etc., need not interfere with employing it to deliver water underground to the house and up to elevated tank. A cock-spout, a packed stuffing box, and a line of pipe below freezing from lift pipe to tank, are the essentials. Delivery to tank should be made over top of tank; and the line should have a cock and drain so that the tank pipe can be emptied when desired, and so that full force for sprinkling can be had by cutting off the tank line. When pumping to the tank, it is merely necessary to have the cock-spout closed and the shut-off of the tank line turned on.

The advantages of having the pump indoors, at the sink, are, (1) that water may be pumped for use directly; and (2) that it is not necessary to go outside in bad weather in order to fill the tank. The indoor pump will also conveniently serve ordinary purposes when other water fixtures of the house are out of repair.

Small *gasoline engines*, by means of pumping jacks or other methods of actuating, are often used to operate pumps. *Hot-air engines* are also frequently used for pumping purposes, such as lifting water to upper floors of buildings whenever the city pressure may be inadequate.

Windmills are a favorite means of operating outside pumps in localities where the mean wind velocity is high enough to run them economically. Light winds, and water at great depths, both contribute to increasing the size and cost of mills; while spasmodic winds require great storage capacity. If the mean wind velocity is under 7 miles per hour, mills are suited to very light pumping only. Windmills require self-priming pumps—that is, pumps that are always ready to pump water without adding priming or working rapidly to get water to the cylinder. They are also provided with governors to avoid pumping after the tank is full, and with means which high winds will automatically operate, for folding the mill out of the wind. Light winds and severe duty are counterbalanced to some extent by gearing the wheel for higher speed than is communicated to the actuating rod.

Hot-air engines can be used indoors if the supply is within the vertical distance limit and not too far from the house. If the well or source is far away, it is best to build a frost-proof house for the engine, close to the source or over the well, so that direct connection to pump-rod can be made. Hot-air engines, like gasoline engines, depend on the momentum of the speed wheel doing part of the work. In the double-cylinder type, illustrated in Fig. 67, heat from wood, coal, gas, or oil expands the air under the piston of the power side, and drives it up. At the same time, the other piston draws the air over through a heat accumulator of iron plates, where it comes in contact with a water-jacket that is filled by passing the pump discharge through it, the air thus losing some of its heat by imparting it to the water in the jacket. The same air is then forced back through the accumulator, where it reabsorbs some of the heat previously parted with, and is compressed in its partially cooled state in the bottom of the cylinder on the combustion side, where, by again absorbing heat from the fuel, the process is caused to be repeated. Thus, by alternate expansion and contraction of the air contained, the engine is operated, the water pumped for general purposes aiding by absorbing heat from the air as it passes through the jacket.

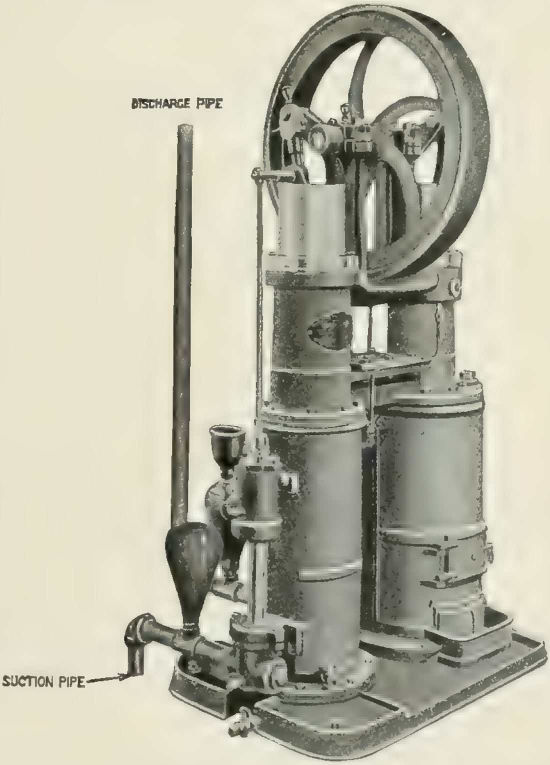


Fig. 67. Double-Cylinder Hot Air Engine for Pumping House Water Supply.

Hydraulic water-lifts have of late years been used to elevate water by water-pressure. With them various arrangements of piping to suit a wide scope of conditions are possible. If city water pressure does not reach the upper floors, the pressure on the lower floor may be employed to lift the supply for the upper floors, either for direct use from the pipe as usual, by aid of a closed accumulator, or by first delivering the water elevated into an open tank and then piping as in the ordinary tank installation. The power-water of a lift (that used to elevate with) is not wasted as in the case of a ram. The service for the low-level fixtures is simply carried through the power cylinder of the lift, and elevation takes place only during the use of faucets connected to the street pressure. The amount of water elevated is therefore governed by consumption on the lower floors; and the ratio of amount elevated to that used directly from the initial pressure, is as the capacity of the power cylinder to that of the one operated by it. An approximate estimation of the relative amounts of elevated and initial supply needed, must, on this account, be made before a lift of proper construction can be selected.

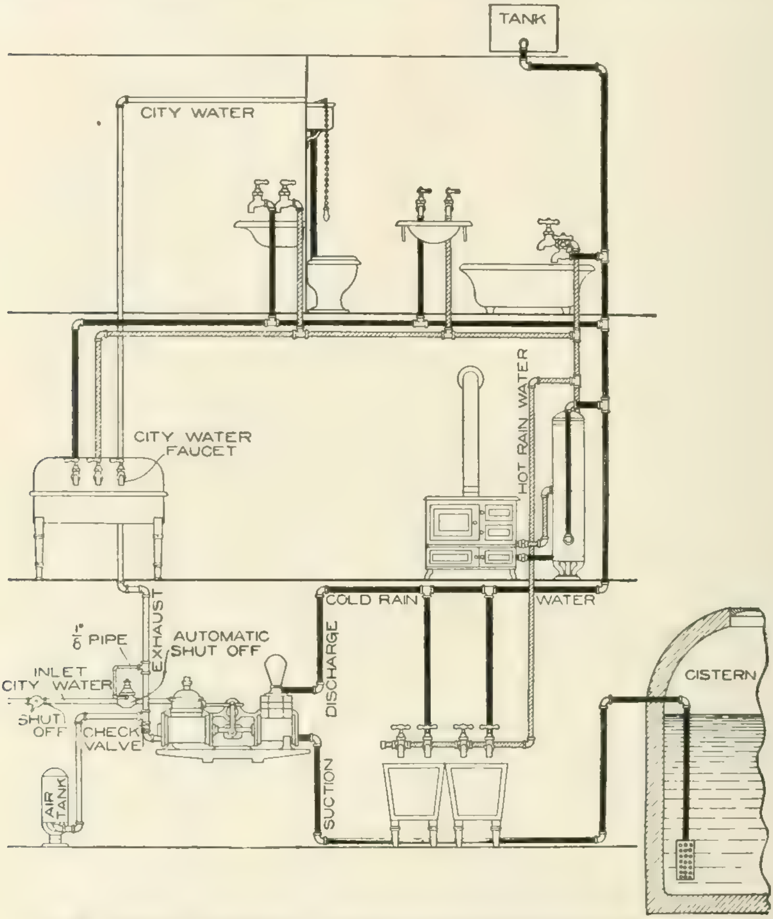


Fig. 68. Method of Using City Pressure to Pump Soft Water for House Supply

Cistern water can also be lifted by this method to either an open or closed tank, using or wasting the power water according to circumstances. In Fig. 68 is shown a plan by which the use of hard city water, useful for some purposes, is made to pump rain water for baths, trays, etc., by means of a water lift.

Domestic supply by what is termed the *Pneumatic System*, is a feature of modern plumbing in many isolated buildings. The manner of pumping, though it may be accomplished by any of the means mentioned, is usually by hand pump. Instead of the open elevated tank supplying the fixtures by gravity, a closed tank capable of withstanding the required pressure is placed either in the cellar or in the ground. The pump is connected with the tank at the bottom, with a check-valve between the pump and tank. The house service is also taken from the bottom of the tank. Pumping the water in, crowds the air in the tank into the upper portion, so that, by the time the tank is three-quarters filled with water, there is in the neighborhood of four atmospheres' (or 45 pounds') pressure on the gauge. Part of the storage tank being occupied by air, and much of the water in it not available under the pressure thus established, higher pressures are often employed, either by pumping air in with a separate pump, or by

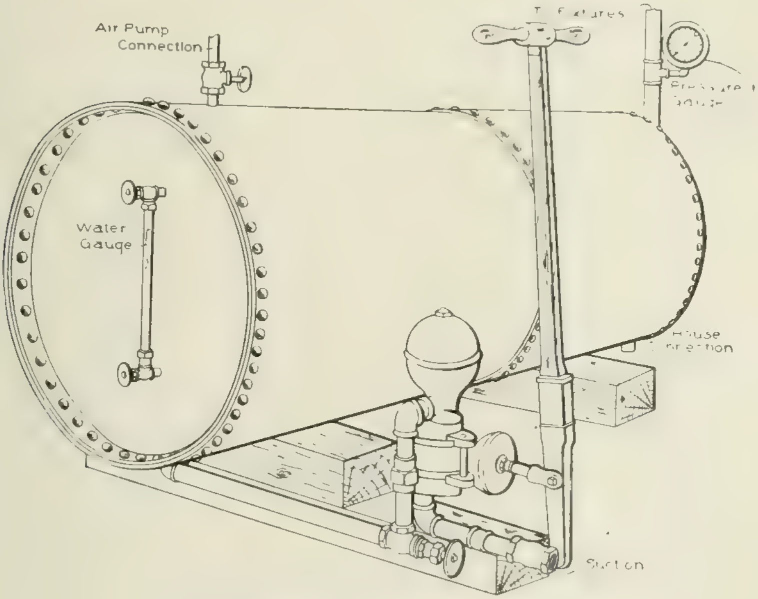


Fig. 69. Pneumatic Water-Supply Apparatus.

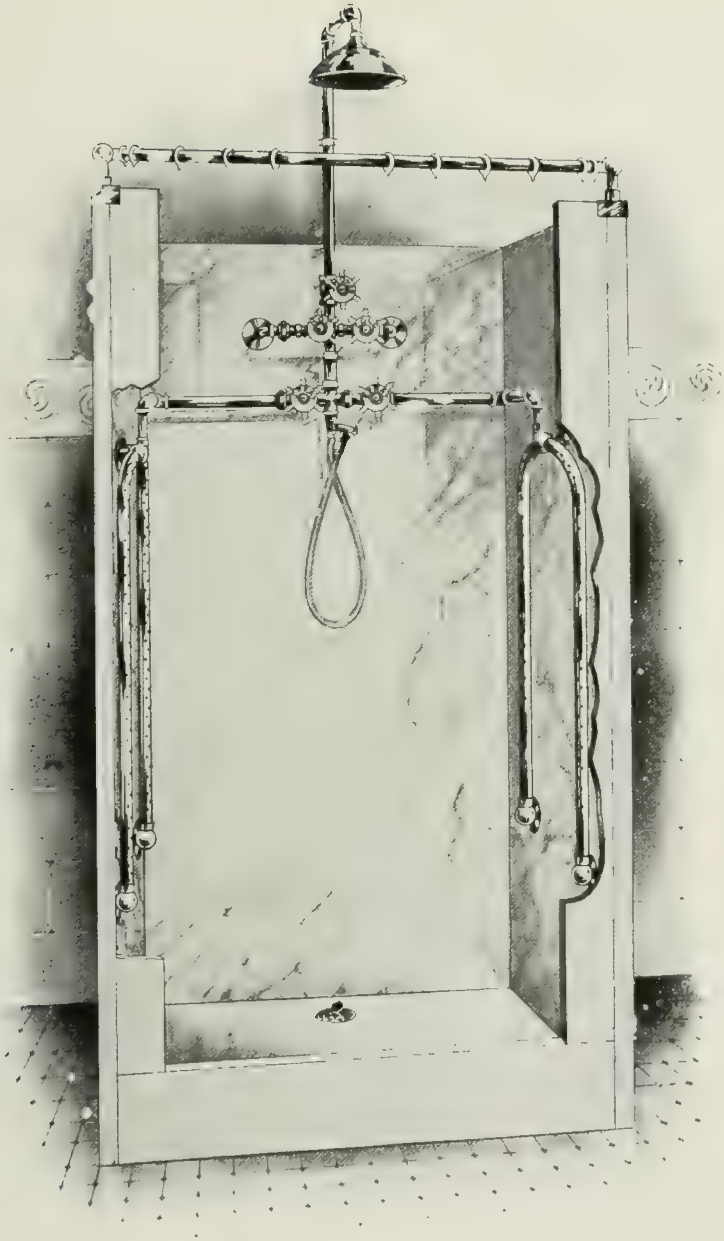
use of a pump delivering both water and air. The former is the more satisfactory.

A type of pneumatic service apparatus is shown in Fig. 69. The good features of these systems are that cheap and permanent support for the tank is secured; the water is kept cool in summer and free of frost in winter; and, if sufficient capacity is provided, fire-pressure for a time can be obtained. The disadvantages are that plain iron cylinders injure the water; galvanized cylinders are costly; large cylinders are hard to make and keep air-tight through the strain of transportation and installation; calking seams is expensive; a battery of small cylinders offer numerous seams and connective joints as chances for leakage, and only a fraction of the water is available under ordinary pressure; high pressure is severe on the pump and parts; and hand pumping is very laborious. Pressure higher than necessary for the purpose, is useless expense in any system.

WASHER AND HYDRANT

Assuming that a house is to be piped from city pressure, the fixtures of the yard are nearly always a street washer and yard hydrant. The principle of these is the same; but the washer is primarily intended for the attachment of hose for sprinkling purposes, while the hydrant body extends above ground so that vessels may be placed under the nozzle to have water drawn into them. The hydrant may be used to draw either with or without a hose thread on the nozzle, while no use of the street washer is possible without the thread; hence there may be a material difference in the water rates, according to the possible uses the water can be put to.

The valve of these fixtures is placed at the bottom, 2 to 5 feet below the surface, according to climate. The working parts can be withdrawn for repairs without disturbing the body. Waste-holes are open when the pressure valve is closed, so that the stem and body will empty to below the freezing point. The pressure waste-hole is not entirely closed until the hydrant or washer is approximately wide open. For this reason, turning the water only partly on when drawing or sprinkling, while it does no apparent harm, is likely to lead to trouble. If the ground is clay, it does not soak up the waste. If there is a cellar near, it will sooner or later find its way into it.



NICKEL PLATED BRASS SHOWER BATH.
The Federal Company.

Even if care is taken in this regard and the hydrant valve fully opened when in use, there is a liability to serious dampness from the wastage into the ground of the water stored in the standpipe above the valve, which is always after a short period discharged below the ground-level through the waste-hole.

The least trouble one may expect from careless use is that the ground around the fixture will be saturated, and the body stand full of water instead of draining away; and when cold weather sets in, damage by freezing will result. The action of frozen ground in pulling up on the body of these fixtures is severe. To avoid trouble from waste water and frost, certain precautions are taken in good work. The end of an iron pipe is too rigid for direct connection. To overcome this, fittings and nipples are added so as to make the connection indirect and secure the required spring in the joints and pipe, as well as freedom from torsion. A short piece of lead pipe answers the same purpose. A cavity formed about the base of the fixture and connections, permits freedom of action and greater immunity from frost breakage.

Usually, the only positive way to insure the waste water draining away harmlessly, is to bore a dry-well under the fixture and fill it with broken rock or fragments of hard brick. This filling should extend a little above the bottom of the fixture, and should have a stout cloth folded about the body and tucked down around the brick at the edges so that the earth cannot wash in and choke the crevices of the filling.

SERVICE PIPES

The supply to the house should have a stop and waste immediately outside the wall—or, preferably, just within the wall if the cellar is frost-proof. For outside use, the iron case box is best. Combination stop and waste cocks or valves of similar principle are generally used for this and all other shut-off purposes in plumbing work, where the waste feature is permissible at all. Two separate valves or cocks serve the purpose perfectly, of course; but the waste is likely to be forgotten, thus leaving the pipe filled and subject to frost. Merely closing the stop and opening the waste will not, however, drain the pipe. It is necessary, also, to open the faucets in the house, in order that air may enter at the upper end of each line and counterbalance the atmospheric pressure at the waste so that the water will run out by gravity. If the pipe is sagged at any point, the water retained will have to be blown out with the lungs. If the pipe is trapped by reason of its course, the trap is, or should be, provided with a drain cock, and this must also be opened to insure thorough draining. Air-chambers usually drain without attention as they are only partially filled by compression of the air trapped in them, and when the pressure is off, the air expands again and drives the water out.

While speaking of draining pipes, it may be well to mention the draining and protection of waste traps from frost as well. Closet tanks can be drained by simply pulling the chain when the water is off. The bowl may be emptied with a sponge or rag; but, as communication would thus be opened between the house and soil pipe, this plan is not advised for any kind of trap. Common salt added to the water in the trap will prevent freezing until the contents chill below zero, Fahrenheit. Caustic soda lowers the freezing point, and may be used in earthenware with impunity; but while it has shown no noticeable effect on metals, it should be used with caution, if at all, in both metal and porcelain-enameled iron fixtures. Glycerine and wood alcohol added in equal parts to make a 30 per cent solution in the trap or fixture, will prevent freezing above zero. If the house is being drained for a considerable period of disuse, the best anti-freezing and seal-protecting filling for ordinary traps is, perhaps, glycerine alone. It has the advantage of doing no injury whatever to any material used in such goods, and it will not evaporate.

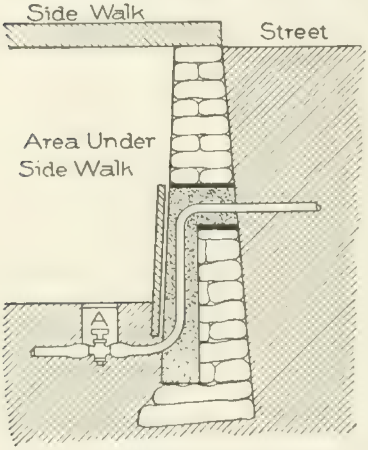


Fig. 70 One Method of Protecting Service Pipes from Frost. Pipe Carried through Wide Channel in Wall and Packed in Mineral Wool.

While it is sometimes necessary to place pipe in exposed positions, plumbing is not satisfactory if so exposed as to freeze during regular occupancy of the house; and every precaution should be taken to locate the fixtures and design the pipe system so that freezing will be unlikely. When exposure cannot be avoided, placing the hot service below the cold on horizontal runs; providing circulation in the hot service so placed; provision for circulation in, or otherwise warming, the cold service; and employment of liberal air-chambers, may singly or otherwise reduce the trouble from freezing to a minimum. Fig. 70 illustrates the precaution taken in one instance to protect the service in a cold-climate job. Water for the whole job always depends upon the service being in working order, and in this case the character of the ground prohibited drilling down to carry it under the area wall. The wall is shown liberally channeled, thus making three walls and the ends of the box of stone. The pipe is packed in mineral wool. The main stop and waste cock is shown at *A*.

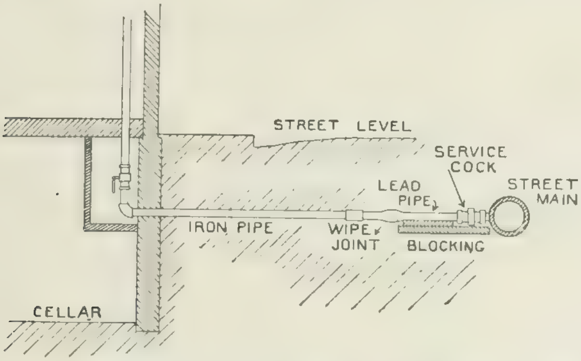


Fig. 71. Iron Service Pipe Connected to Street Main by Lead Pipe to Secure Flexibility and Avoid Effects of Settling.

Fig. 71 shows a method of securing flexibility necessary to compensate for settling when connecting an iron service pipe with the street main, a section of lead supply being wiped in next the main. The service box and stop-cock at the curb are not shown in the engraving. The earth under the pipe should be rammed down solid after the connections are made, so that pressure from above will not break the connection or strain the cock. The connections between the lead and iron pipes should be made by means of brass ferrules

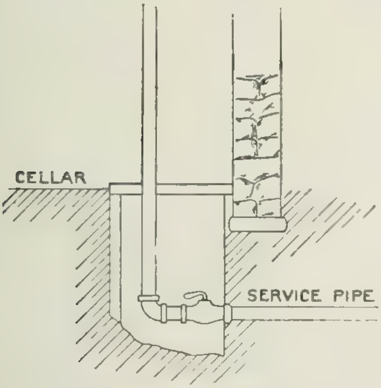


Fig. 72. Service Pipe Carried beneath Foundation Wall.

and wiped joints. A stop and waste cock should be placed in the service pipe just inside the cellar wall, and in a position where it will be accessible in case of accident. A drip pipe should be connected with the cock tube, for draining away the waste water, which would otherwise saturate the frost-proofing and chill the pipe by conduction.

Simple boxes with multiple walls with air-space between, may be employed in protecting pipes against frost; or a single box with mineral wool, hair, felt, shavings, or granulated cork may suffice. When the service is brought under the foundation before entering the cellar, as shown in Fig. 72, frost-proofing is seldom necessary.

DIRECT SUPPLY

The salient features of the supply system for city pressure, not already mentioned, are; separate shut-off cocks for the supplies of each fixture; separate lines to each isolated fixture or to each group of fixtures; ¾-inch supply to all sinks, trays, and baths; ½-inch supply to water-closet tanks; and ½ or ⅜-inch branches for lavatories; no traps in supply lines; return circulation from lavatory hot supply so that hot water can be drawn instantly at the lavatory faucet; storage cylinder for hot water amply large to furnish a hot bath without robbing the hot service for other purposes; faucet on sediment pipe, so that water can be drawn at that point when desired; and proper stove connection. All shut-offs in direct-pressure work, except where located immediately at the fixture, should be *stop and waste,* with the waste on the house or fixture side.

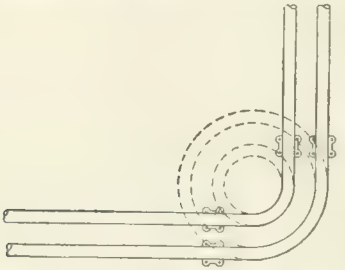


Fig. 73. Method of Laying Out Concentric Bends in Parallel Pipes.

On single runs of lead pipe, make all bends on the same size of pipe, of the same radius. Make no bend on any size pipe, except tubing, of less than 3-inch radius to the center of the pipe. Give ⅝ and ¾-inch pipe bends 3-inch radius; and ⅞ and 1-inch pipe bends, 4-inch radius. Where two pipes of different size run together and bend in opposite directions, give the bend of the smallest pipe the radius prescribed for the bend in the larger one, if practicable.

TABLE III

Data Relating to Offsets

Bend	Equal to	Multiply by
$\frac{1}{6}$	60°	1.15
$\frac{1}{8}$	45°	1.414
$\frac{1}{12}$	30°	2.00
$\frac{1}{16}$	22½°	2.61
$\frac{1}{32}$	11¼°	5.12
$\frac{1}{64}$	5⅝°	10.22

Where more than one pipe bend in the same direction, make the bends of the pipes form arcs of concentric circles as shown in Figs. 73 and 74. To set off the offsets in Fig. 74, draw line *A*, at the end of the first bends; and with the proper radii, describe the arcs that outline them. Set off one-eighth of the circumference of the circle corresponding to the larger arc, and draw line *C*, cutting the center of the circle. Then produce dotted line *D*, and set off a square the diagonal of which will give the straight pieces of the offset desired; and produce *E* parallel to *C*. Next describe the arcs outlining the second bends, finding the center on *E* from radius equal to the corresponding radius at *A*, which will be at the intersection of *E* and *B*. This brings the offset parts the same distance apart as the runs are. To accomplish this result with iron pipe, the centers of 45-degree fittings would have to be placed at the intersections of tangents of the arcs, thus throwing the fittings in a line deviating 22½ degrees from one perpendicular to the run. This plan is the strictly correct way; but on account of the difficulty of laying out the work, it is more usual

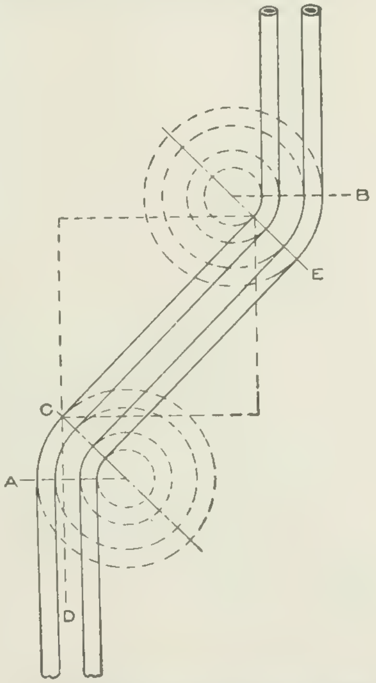


Fig. 74. Method of Laying Out Offset in Parallel Pipes to Preserve Equal Distance between Them.

to line up offset fittings perpendicular to the runs, and let the offset pieces fall, as they will, nearer to each other, center to center, than are the lines of the runs.

Offset pieces from center to center of fittings exceed in length the distance offset in the ratio indicated by the constants given in the accompanying table. To find the length of an offset piece, center to center of fittings, simply multiply the distance the line is to be offset, by the constant given for the particular fittings to be used.

Water Supply to Fixtures. In a small installation, the running of a separate supply to each fixture is desirable. There is, however, a limit to the number of fixtures and isolated location of them, beyond which the furnishing of separate supplies to each faucet is folly, as, in addition to the confusion of pipes, and the expense, it leaves more material open to possible failure, and does not reduce the chances of lack of service in proportion, the sole object of separate supplies (and of cocks, too) being to avoid losing the service of other fixtures during times when one of them, or its supply or waste, must be repaired.

In a residence job, two main supplies to each bathroom, with separate stops for each fixture, are sufficient; and a return circulating pipe from the lavatory will serve every purpose, as the water is kept hot in the main line to the bath branches.

The pump and kitchen-sink work of a country job of this type is shown in Fig. 75. The pump air-chamber discharge leads up to and over tank. An opening near the pump provides for elevating water by other means if desired. The pump faucet is piped up and over so as to discharge into sink. The tell-tale pipe from tank leads down behind sink-back and out through a nozzle, as shown. The sink supplies are fitted with stop-cocks. The pressure being light, there are no air-chambers to the sink faucets. The supply to pump is from a large cistern.

Fig. 76 shows the supplies of the same job, on the kitchen ceiling. The system provides positive circulation to keep hot water near the bathroom fixtures. The hot supply is on the left side for each fixture. There is only one pipe crossed, and it does not interfere with draining the job. There are no traps in the supplies, nor drain cocks, to be forgotten. There is a relief line from the reservoir to the tank, so that it is not possible to close every means of escape for vapor or steam

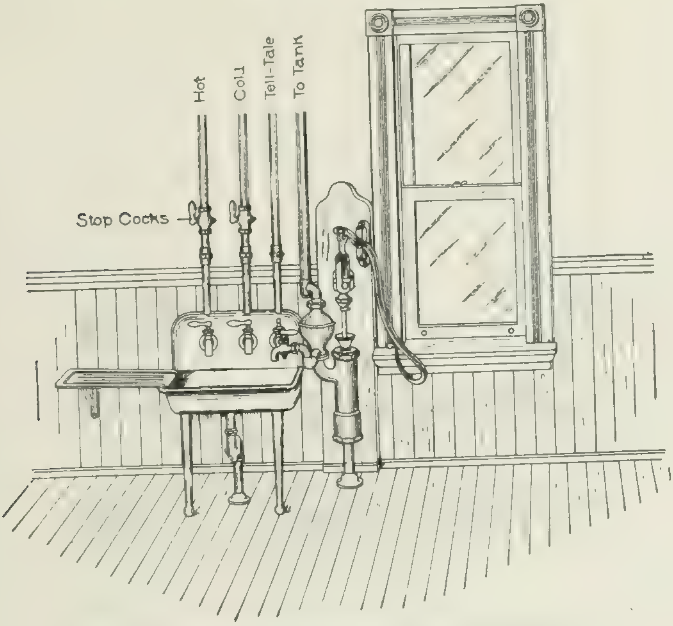


Fig. 75. Pump and Kitchen-Sink of a Country Installation.

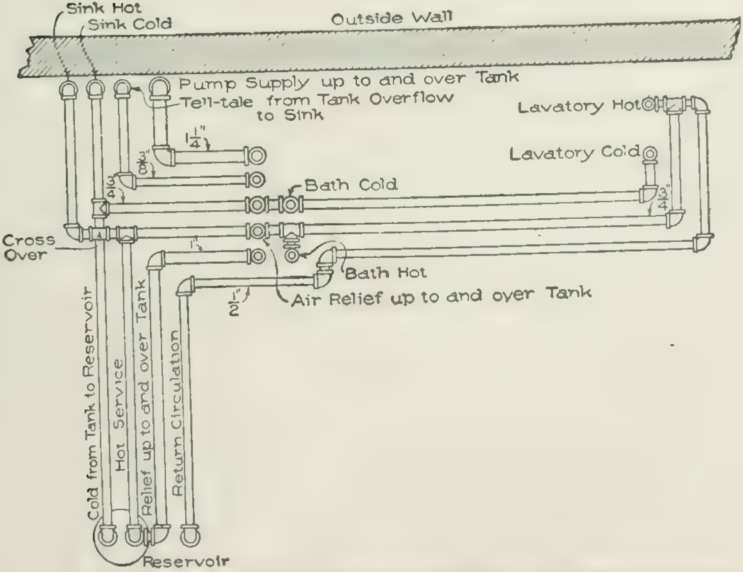

Sink Hot
Sink Cold
Outside Wall
Pump Supply up to and over Tank
Tell-tale from Tank Overflow to Sink
Lavatory Hot
1¼"
Lavatory Cold
3/8"
3/4
Bath Cold
3/4"
Cross Over
1"
Bath Hot
Air Relief up to and over Tank
1/2"
Cold from Tank to Reservoir
Hot Service
Relief up to and over Tank
Return Circulation
Reservoir

Fig. 76. Plan Showing Layout, on Kitchen Ceiling, of Supply Pipes in Installation Shown in Fig. 75.

from the reservoir. The hot supply and cold service are both open to the air at the tank.

The disadvantage of this job is that the cocks which stop the hot water to the bathroom are over the reservoir. While each fixture is controlled separately, by cocks in addition to its regular faucets, all the lines are not under control individually. This arrangement embraces every feature essential to good service and with the least possible material. The nickeled supply in bathroom is thus reduced to a minimum, and the chances for leakage to do damage are greatly lessened. For comparison, the kitchen work of an actual installation with separate supplies, having one bathroom and three odd fixtures, is shown in Fig. 77. This number of fixtures is considered about the limit in strictly separate supply work for residences, when all the lines radiate from one point, as they do in this case. In order that their purpose may be understood, the pipes shown in Fig. 77 are numbered. Pipe 1 carries the water from the house force-pump to the tank, and is arranged to discharge over the top of the tank. The tell-tale pipe, 2, is from the tank, and discharges in the sink, so that the person using the pump will know, when water flows from it, that the tank is full to overflowing. The cold-water supply to the butler's sink is No. 3. No. 4 is the hot-water supply to the same fixture. Pipe 5 is the return circulation from the bathroom hot supply. To make proper circulation certain at all times, regardless of the trap in the hot-service pipe made by dropping from the boiler and running across under the sink before rising to the second floor, the hot-service pipe is continued to the attic and a return made from there, an air-pipe being taken from the highest point over the tank, to prevent its becoming air-bound. The position of the stop-cocks is such that they will drain without giving special attention to the waste water, which discharges into the sink; and the cocks are within easy reach from the floor. Pipe 6 is the cold-water supply to the bathroom fixtures. The supply to the water-closet tank is taken from pipe 9, which passes under the closet room, a cock being placed just above the floor. Pipe 7 is the hot-water supply to the bathroom fixtures. The main cold supply from the tank is pipe 8, which has a cock over the sink, and is also provided with a valve at the tank. Pipe 9 supplies cold water to the laundry, the hall lavatory, and the water-closet already mentioned. Pipe 10 supplies hot water to the laundry and the hall lavatory.

All of the service pipes, both hot and cold, above the first floor, are continued upward from the kitchen ceiling through a partition to and over the tank. This allows air to enter the pipes and drain the lines when the stop-cocks on them are turned off.

Baths do not need circulation for the same reason that lavatories do. Lavatory faucets are small in nozzle, as a rule; only small quantities of water are needed at a time; and it is annoying to have to waste time in drawing out cold, "dead" water and enough more to warm the pipe line, before warm water can be had at the faucet. Where the water must be pumped by hand this is still more aggravating. Kitchen sinks are close to the hot supply source, and do not need circulation. Lavatories and other fixtures remote from the bath or main toilet room, are sometimes served from the circulating loop instead of separately.

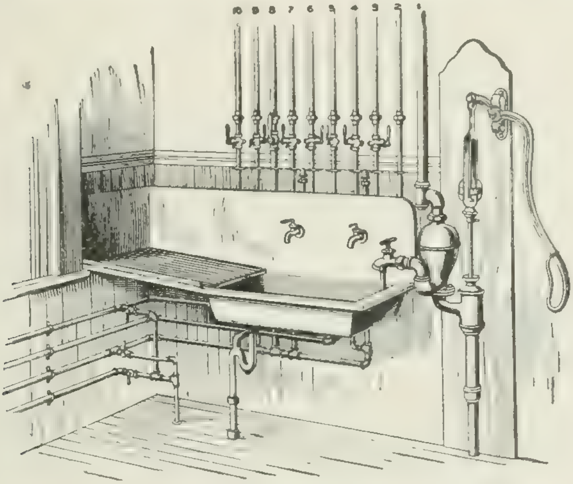


Fig. 77. Kitchen Arrangement of a Separate Supply Tank Installation.

Hot-Water Storage. The storage cylinder for hot water is made in both horizontal and vertical types. When heated by stove connections, the vertical type, shown in Fig. 78, is best; and this type is usually employed. The only difference in the standard makes is the position of the connections. Both vertical and horizontal types are connected and operate on the same principles, and the arrangement of one may be deduced from the *modus operandi* of the other. The vertical type, for example, of iron or mild steel, galvanized inside and out, single- or double-riveted, heavy, and calked according to pressure designed for, is generally divided into two classes—*Standard* and *Extra Heavy.* Seamless copper cylinders, reinforced inside for heavy work, are made.

The light copper shells for light pressure, not reinforced, are collapsible under partial vacuum, and frequently do collapse when the supply is being drained, on account of the delivery failing to admit air to take the place of the water. Copper shells are also much more likely to rupture under strain than iron or steel shells. Take, for instance, a house with copper storage cylinder, with hot fire and in extremely hot water, as on wash-day; then, if the pressure is suddenly reduced by opening a faucet or otherwise, and the temperature is far above the boiling point of the water under the remaining pressure, the tendency is for the whole volume of water to turn instantly to steam. This has happened with disastrous effect in more than one instance, the copper shell being ripped and spread out almost in a plane.

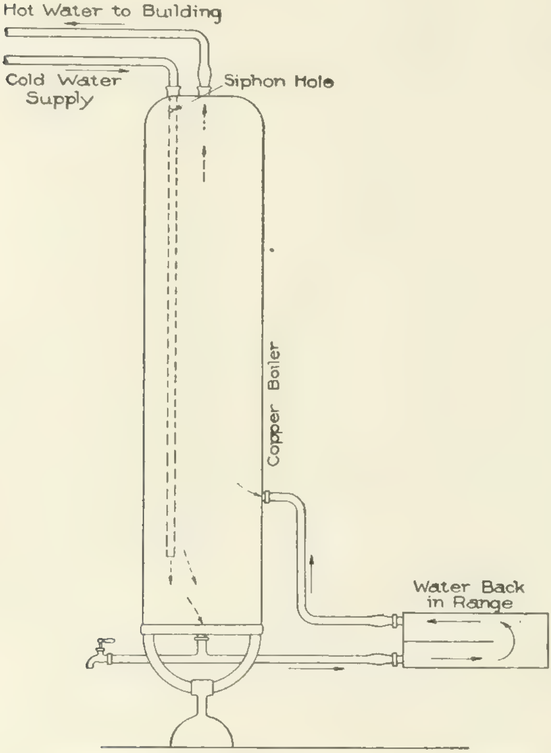


Fig. 78. Vertical Type of Hot-Water Storage Cylinder Adapted for Range Heating.

Rumbling noise is frequently heard in any type of reservoir. Water being heated throughout, or perhaps only at some points in the stove, to above the boiling point corresponding to the pressure, steam bubbles form in the hottest places and crowd the water-back into the main or into the air-chambers to make room for themselves. It is the concussion caused by the collapse of these bubbles forming and condensing in rapid succession, that creates the rumbling noise. This condition sometimes results from a brisk fire when the reservoir water is not overheated, and is due to air-traps in the connection, or constriction by incrustation or otherwise. Rumbling under this condition is a cause for prompt investigation.

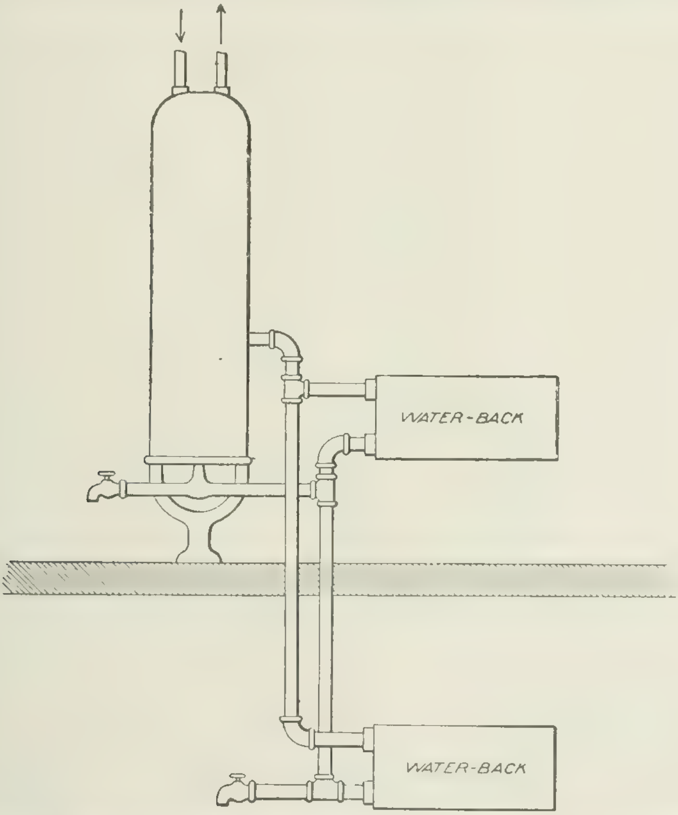


Fig. 79. Method of Connecting Reservoir to Two Water-Backs on Different Floors.

The means of heating may be a cast back or front, or a hand-made pipe coil in the firebox. Air-traps favoring the formation of steam are occasioned by wrong inclination of the connection, by reduction of its diameter in the horizontal part, or by the upper hole of a cast back being tapped below the top of the water cavity. The bottom of a reservoir is below the firebox level when placed on the regular stand. When it is desirable to connect a reservoir with two water-backs, one in the kitchen range for regular service and another in a laundry stove in the cellar, the plan of connecting them seen in Fig. 79 is proper. In this case, either stove may be used separately, or both together, as occasion demands. The sediment cock of the upper reservoir may be handy to draw from at times; but the lower one will be found to collect most of the sediment, and should be opened quite frequently to cleanse the water-back and connections.

In laundries, public bathrooms, etc., where a large amount of hot water is used, it is necessary to have a larger storage tank and a heater with more heating surface than can be obtained in the ordinary range water-back. Fig. 80 shows an arrangement for this purpose, using the horizontal type of storage tank. The tank may be of galvanized wrought iron or steel, any size desired, and is usually suspended from the ceiling by means of heavy iron stirrups. The heaters used are similar to those employed for hot-water house warming. The simplest method of making the connections is indicated in the illustration. If the supply is from a street service, or there are faucets on the storage tank supply below the hot storage reservoir level, making it possible for the tank to become empty through those faucets or failure of the street supply, there should be a check-valve in the cold-water connection.

The *capacity of the heater and tank* employed will depend upon the amount of water used. In some cases a large storage reservoir and a comparatively small heater are preferable, and in others the reverse is more desirable.

The required grate surface of the heater may be computed as follows:—First determine or assume the number of gallons to be heated per hour, and the required rise in temperature. Reduce gallons to pounds by multiplying by 8.3, and multiply the result by the rise in temperature to obtain the number of thermal units. Assuming a combustion of five pounds of coal per square foot of grate, and an efficiency of 8,000 thermal units per pound of coal, we have the formula:

$$\text{Grate surface in sq. ft.} = \frac{\text{Gal. per hour} \times 8.3 \times \text{Rise in temp.}}{5 \times 8{,}000}.$$

Example. How many square feet of grate surface will be required to raise the temperature of 200 gallons of water per hour from 40 degrees to 180 degrees? Substituting values in the above formula, we have:

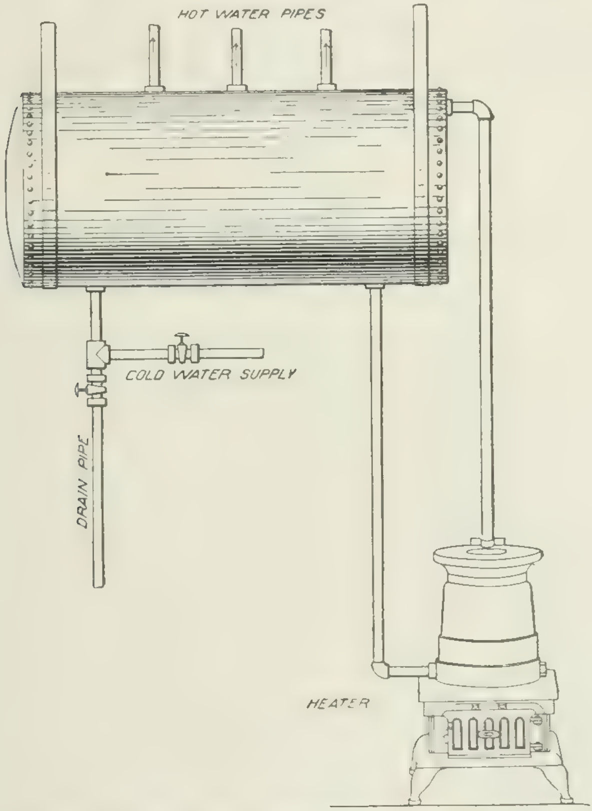


Fig. 80 Horizontal Type of Hot-Water Storage Cylinder Connected to Heater.

$$\frac{200 \times 8.3 \times (180 - 40)}{5 \times 8{,}000} = 5.8 \text{ square feet.}$$

In computing the amount of water required for bathtubs, it is customary to allow from 20 to 30 gallons per tub, and to consider that the tub may be used three or four times per hour as a maximum during the morning. This will vary a good deal, depending upon the character of the building. The above figures are based on apartment hotel practice.

Storage cylinders or reservoirs for hot water are often called *boilers,* but will henceforth be referred to as *reservoirs.* A stove or range connection is essentially described as follows: The sediment pipe should terminate in a faucet at the lowest point in the bottom connection, which connection should rise continuously from the lowest point to the bottom hole in the heater. No direct connection should ever be made between the water supply pipes and the drain. Even if such a connection is above the trap of a fixture, there is some danger that foul liquids or gases may penetrate for some distance into the supply pipes and thus afford a possibility of contamination of the water supply. The upper connection should rise continuously from the upper hole of the heater to the hole in the side of the reservoir; or, if preferred, in order to get hot water instantly after the fire begins, the upper connection may rise and connect into the main hot service over the reservoir. The circulation will be the same; but in general, connecting at the hole in the side gives best results, though in this case the first portion of water heated mingles with the balance in the upper end of the reservoir, and the following portions in succession, so that no *hot* water can be obtained until all the water above the side hole is warmed. The bottom hole serves for emptying, cleansing, and circulation to the stove.

The return circulation is always connected to the bottom pipe of the stove connection, as shown in Fig. 81, in which the hot service and circulating pipe are represented by dotted lines. The side hole is simply to receive the water from the stove. There are, or should be, two holes in the top, one in the center of the head, and the other about half the radius in the direction of the side hole. The eccentric hole is for cold-water entry. The cold supply might be admitted at the bottom, but the result would be to empty the reservoir when the house supply is turned off. The cold supply is not emptied abruptly into the top of the reservoir. A delivery pipe is extended to very near the bottom, say within two or three inches, so that the water will mingle directly with the coldest portion near the bottom, where it begins its journey to the stove to be heated. The usual way is by simple open-end pipe, but the end of the pipe should be plugged and holes drilled in the pipe and plug so as to form a spray delivery. This does not aid the delivery or heating at all, but the spray will scour the bottom and sides adjacent when the reservoir is emptied and flushed to rinse out scale and sediment. Immediately under the upper head, the delivery pipe must have a $\frac{1}{8}$-inch hole drilled in, so that air will enter and break the siphon, and thus avoid inadvertently emptying the reservoir when intending only to cut off the supply and drain the pipe. See Fig. 78.

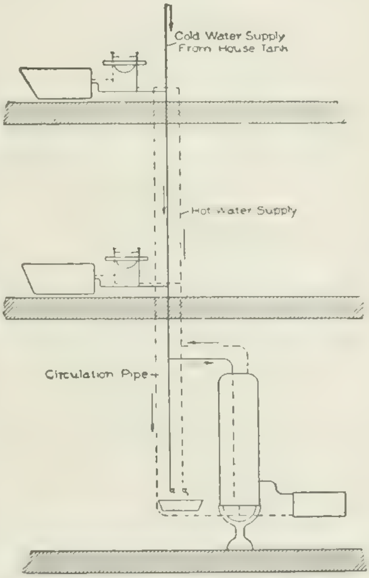


Fig. 81. Pipe Connections to Heater and Fixtures. Hot Service and Circulating Pipe Shown by Dotted Lines. Return Circulation Connected to Bottom Pipe in Water Back.

The *siphon hole*, as it is termed, should be turned in the direction opposite the eccentric hole, which is for the hot-water exit, so that the stream of cold water which issues there when water is coming into the reservoir will not cut across and interfere with the hot service which is always leaving the reservoir at the same time. If the delivery were placed nearest the side hole, hot water from the stove would have to pass around it in order to reach the exit. Delivering the cold through a pipe passing down through the volume of hot water is no material retardation of the heating process. The heat thus absorbed by the cold delivery is simply that much aid to the ultimate purpose. This cannot be said of the siphon-hole jet when directed across the hot exit or in its direction.

The object in putting the siphon-hole near the upper head is to avoid siphoning more water than necessary, as the waste tubes of stop and waste cocks are generally left open—not connected to drains, and often not even discharging where the waste can be left to take care of itself. Moreover, it is a waste of the stored hot water to siphon out several inches from the hottest point.

Care should be taken not to have the hot connection extend into the upper head below the inner surface, as this would form an air-space which could not be filled with water, and thus annoying noise and the formation of steam would be favored, if no other consequence presented itself.

It is essential to keep the water-back or coil filled. Sometimes the supply may be off for a day or so. No water can then be drawn at the regular faucets; and extreme care should be taken not to draw too much from the sediment faucet, as this is the time when temptation to use it is hard to overcome. The reservoir full will keep the level above the side hole for weeks, if none is deliberately drawn out. The height of the water can be told by tapping on the shell, and in no case should it be allowed to fall below the side opening; neither will it do to empty the reservoir and use the fire with the back empty. Either keep water in the reservoir in cases of emergency, or remove the water heater altogether and substitute a tile back until regular water supply can be had. A reservoir can be replenished with a pail and funnel, by hand, by loosening one of the top connections.

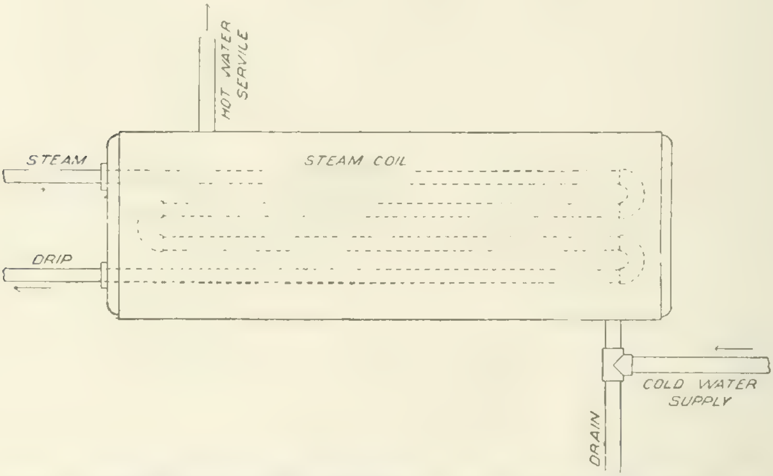
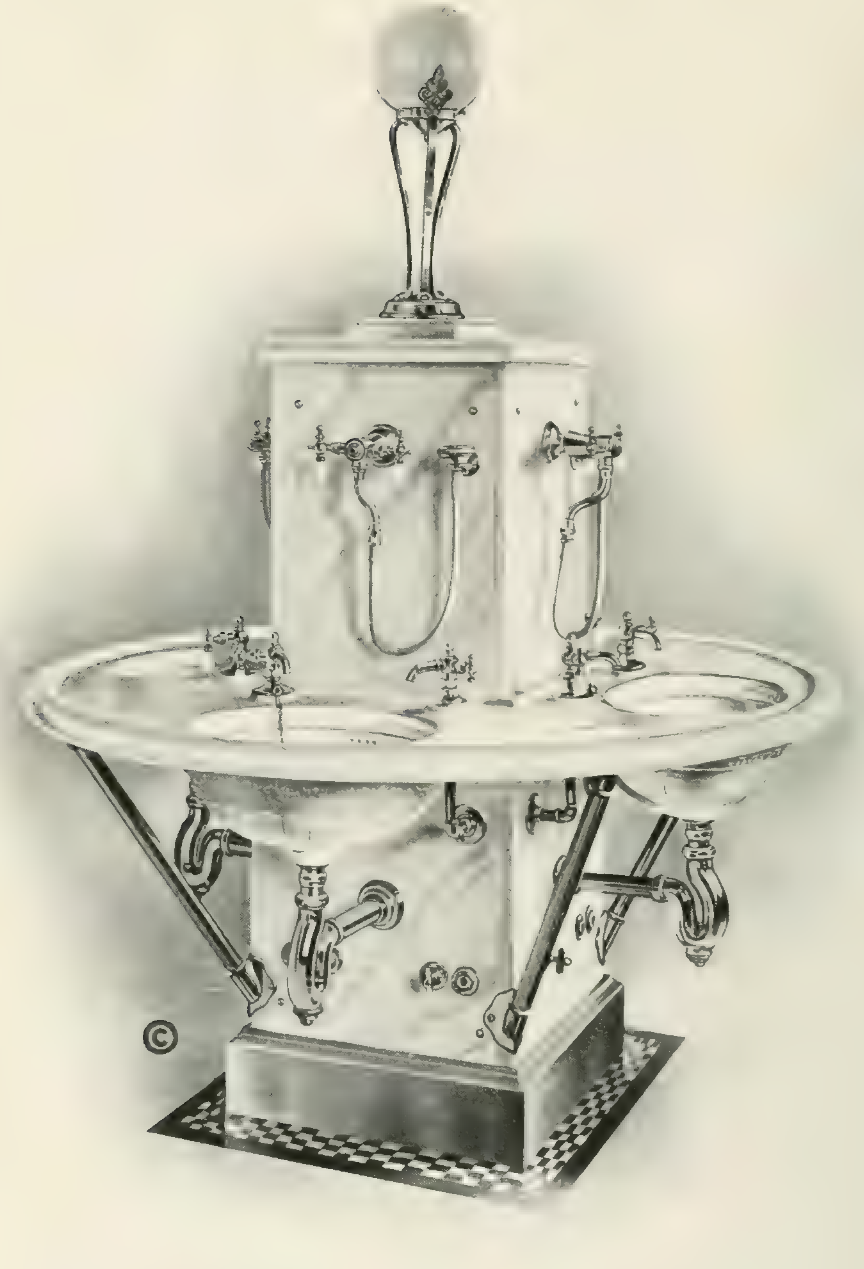


Fig. 82. Horizontal Hot Water Storage Reservoir with Steam Coil of Brass Pipe for Heating. Used Where Steam Pressure is Constantly Maintained.

In apartment or other houses where steam pressure is constantly maintained, the whole plumbing system is usually supplied with hot water through the medium of a reservoir provided with steam coil of brass pipe, as shown in Figs. 82 and 83. The *trombone coil*, illus-



FOUR-BASIN BARBER LAVATORY
Constructed of Italian Marble with Tennessee Marble Base
James B. Clow & Sons, Chicago

trated in Fig. 82, can be used only on horizontal tanks; it would not drain in any other position. The water of condensation is generally wasted into the sewer, delivered to a hot well, or returned by steam trap. Steam heat in such instances takes the place of the water heater used in stoves and ranges in general domestic work.

The efficiency of a steam coil when surrounded by water is much greater than when placed in the air. A brass or copper pipe will give off about 200 thermal units per square foot of surface per hour for each degree difference in temperature between the steam and the surrounding water. This is assuming that the water is circulating through the heater so that it moves over the coil at a moderate velocity. The ratio of absorption decreases as the temperature of the water approaches that of the steam surface. In assuming the temperature of the water, take the average between that at the inlet and that at the outlet.

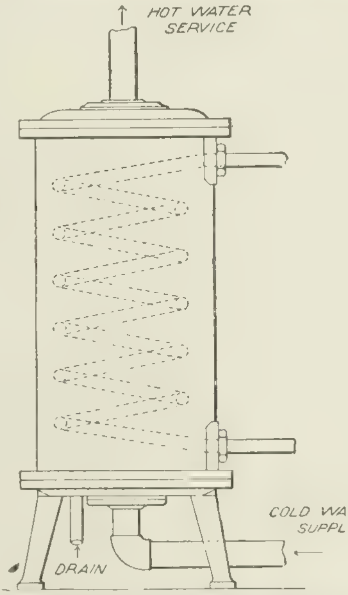


Fig. 83. Vertical Storage Reservoir with Steam Coil of Brass Pipe for Heating. Used Where Steam Pressure is Constantly Maintained.

Example. How many square feet of heating surface will be required in a brass coil to heat 100 gallons of water per hour from 38 degrees to 190 degrees, with steam at 5 pounds' pressure?

Water to be heated = 100 × 8.3 = 830 pounds.

Rise in temperature = 190 − 38 = 152 degrees.

Average temperature of water in contact with the coils

$$= \frac{190 + 38}{2} = 114 \text{ degrees.}$$

Temperature of steam at 5 pounds' pressure = 228° approximately (actually 227.964°).

The required B. T. U. per hour = 830 × 152 = 126,160.

Difference between the average temperature of the water and the temperature of the steam = 228 − 114 = 114 degrees.

B. T. U. given up to the water per square foot of surface per hour = 114 × 200 = 22,800. Therefore, No. of feet of heating surface required

$$= \frac{126{,}160}{22{,}800} = 5.5 \text{ square feet.}$$

EXAMPLES FOR PRACTICE

1. How many linear feet of 1-inch brass pipe will be required to heat 150 gallons of water per hour from 40 to 200 degrees, with steam at 20 pounds' pressure? Ans. 21.3 feet.

2. How many square feet of grate surface will be required in a heater to heat 300 gallons of water per hour from 50 to 170 degrees? Ans. 7.4 sq. ft.

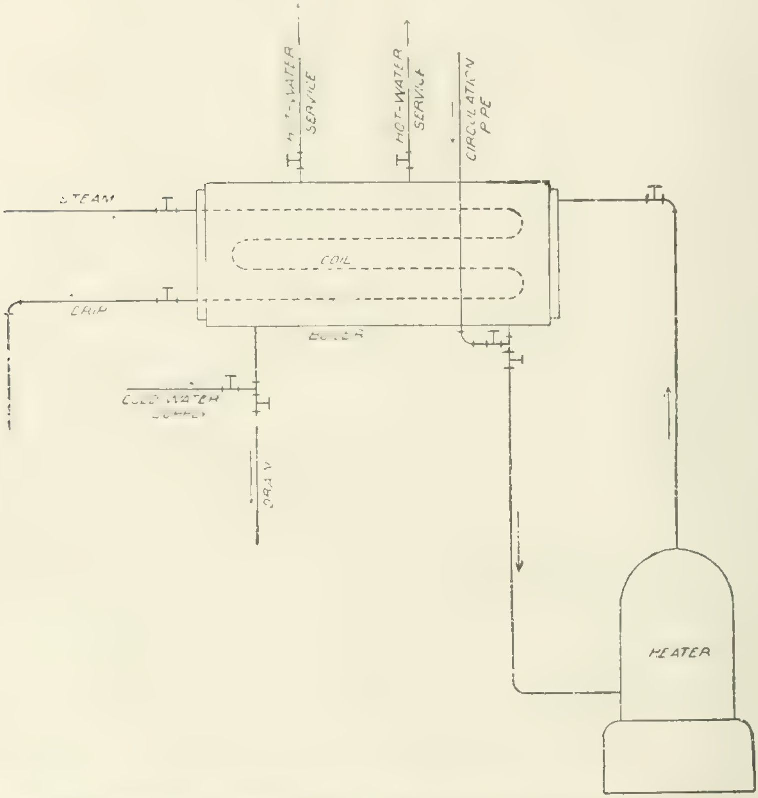


Fig. 84. Storage Tank Heated by Steam Coil in Winter; Cross-Connected to Coal Heater in Summer.

3. A hot-water storage tank has a steam coil consisting of 30 linear feet of 1-inch brass pipe. It is desired to connect a coal-burning heater for summer use, which shall have the same capacity. Steam at 5 pounds' pressure is used, and the water is raised from 40 to 180 degrees. How many square feet of grate surface are required? Ans. 5.9 sq. ft.

4. A hotel has 30 bathtubs, which are used three times apiece between the hours of seven and nine in the morning. The hot-water system has a storage tank of 400 gallons. Allowing 20 gallons per bath, and starting with the tank full of hot water, how many square feet of grate surface will be required to heat the additional quantity of water within the stated time, if the temperature is raised from 50 to 130 degrees?

Ans. 11.6 sq. ft.

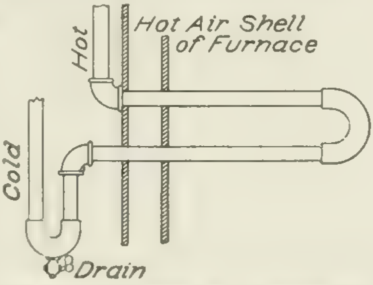


Fig. 85. Cross Connection of Storage Tank to Firepot of Furnace.

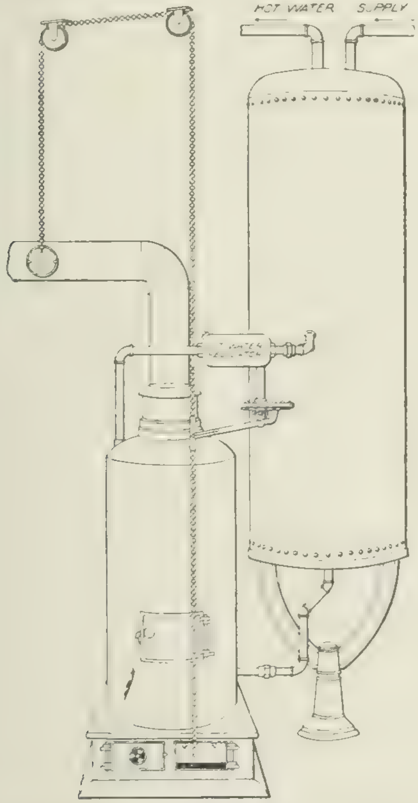


Fig. 86. Temperature Regulator Attached to Coal Heater.

If steam at 10 pounds' pressure is used instead of the heater, how many square feet of heating coil will be required? Ans. 15.3 sq. ft.

Sometimes a storage tank is connected with a steam-heating system for winter use, and cross-connected with a coal-burning heater for summer use when steam is not available. Such an arrangement is shown in Fig. 84. A cross-connection for the same purpose is often made to the fire-pot of the house-warming heater, as indicated in Fig. 85. A drain at the lowest point is essential, but so deep a dip as shown is not necessary.

Temperature Regulation. Hot-water storage tanks having special heaters or steam coils, should be provided with some means for regulating the temperature of the water. Fig. 86 shows a simple form attached to a coal-burning heater. It consists of a hollow casting about nine inches long, tapped at the ends to receive 2-inch pipe, and containing a second shell called the *steam generator*, shown in detail in Fig. 87. The outer shell is connected with the circulation pipe as shown in Fig. 86. The generator is filled with kerosene, or a mixture of kerosene and water, depending upon the temperature at which it is wished to have the regulator operate. The inner chamber connects with a space below a flexible rubber diaphragm in a sepa-

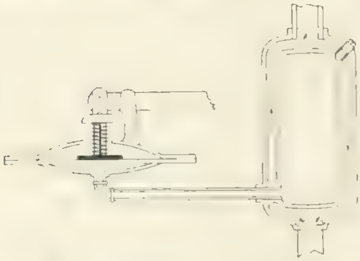


Fig. 87. Steam Generator of Temperature Regulator Shown in Fig. 86.

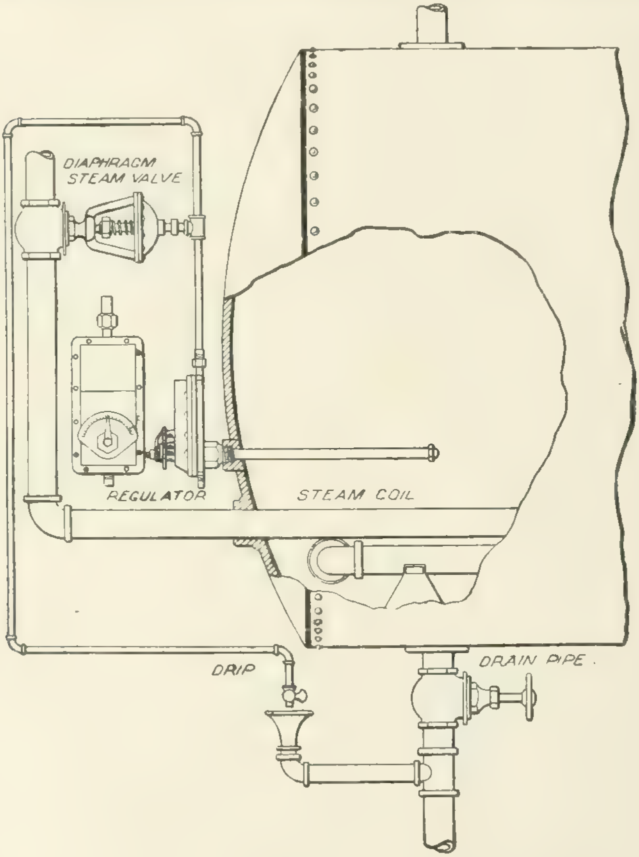


Fig. 88. Temperature Regulator Connected to Steam Coil.

rate case adapted to operate the draft lever. The boiling point of the mixture in the generator is lower than that of water alone, and depends upon the proportion of kerosene used, so that when the temperature of the water in the outer chamber reaches this point, the mixture boils, and its vapor creates a pressure which moves the diaphragm and closes the draft door of the heater, with which it is connected.

A form of regulator for use with a steam coil is shown in Fig. 88. This consists of a rod made up of two metals having different coefficients of expansion, and so arranged that the difference in expansion will produce sufficient movement to open a small valve when the water reaches a given temperature. This allows water pressure from the street main with which it is connected, to flow into a chamber above a rubber diaphragm, thus closing the steam supply to the coil. When the water cools, the rod contracts, and the pressure is released above the diaphragm, allowing the valve to open and thus again admit steam to the coil.

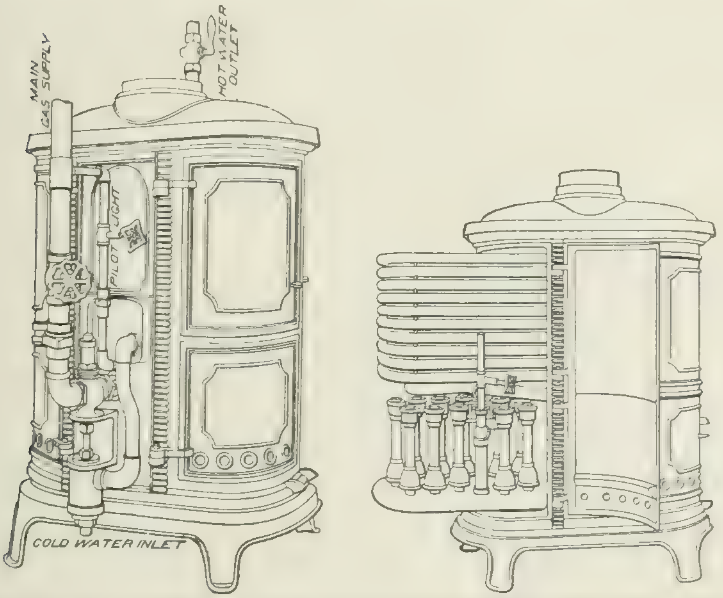


Fig. 89. Gas Heater with Automatic Mechanism for Controlling Hot Service. View at Right Shows Interior Coils.

Return circulation is provided in these installations in the way already described, being even more essential than in small jobs with shorter runs and fewer fixtures; yet one would think that the great number of fixtures served would insure at least one or another being in constant use, and thus keep warm water in the main lines without special provision for the purpose.

In cottages with no bath and with small culinary requirements,

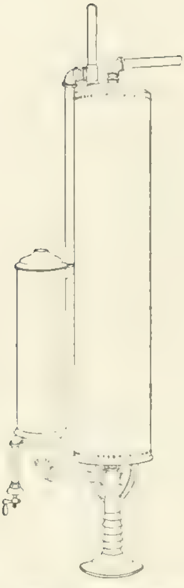


Fig. 90. Gas Heater Connected to Reservoir and Controlled by Thermostatic Valve Projecting into Latter.

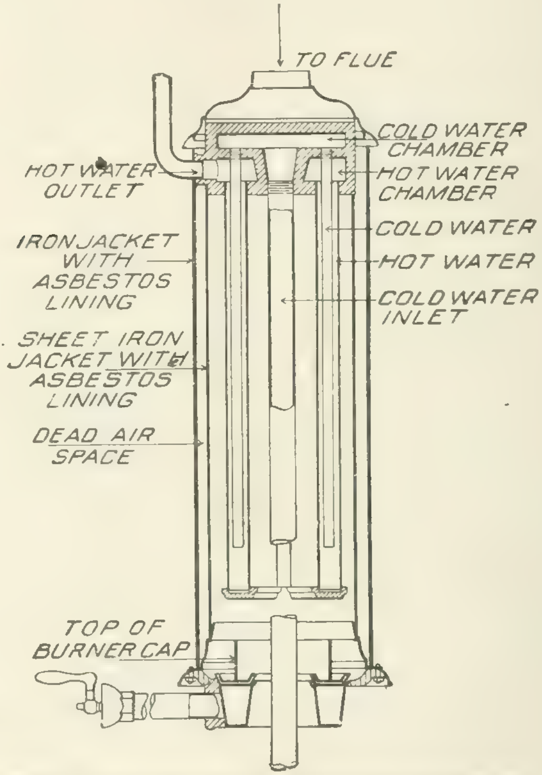


Fig. 91. Enlarged Section of Gas Heater Shown in Fig. 90.

a 30-gallon reservoir is sufficient. Not less than 40 gallons should be employed for a bathroom job. The capacity of the average stove heater is even too great for 40 gallons' storage unless there is liberal use of hot water; but where gas is used and the water heating independent of the cooking heat, as it generally is, the temperature can be regulated to suit. A storage capacity of 52 gallons or more is usual for large residences.

Gas Heaters. There are gas heaters provided with thermostatic or pressure mechanism by which the hot service is taken care of automatically. The latter of these are simply connected in the line in a convenient place. In one type, the appearance and construction of which is shown in Fig. 89, simply opening any hot-water faucet reduces the pressure, and the gas is thereby turned on. A pilot light ignites it, and the supply is heated as fast as it passes through the copper coils of the heater. No storage capacity is required by this form. In another form, shown in Fig. 90, the heater is controlled by a thermostatic valve projecting into the regular reservoir used with it. When the water in the reservoir is heated to the desired temperature, the gas supply is reduced or cut off. A section of this heater is shown

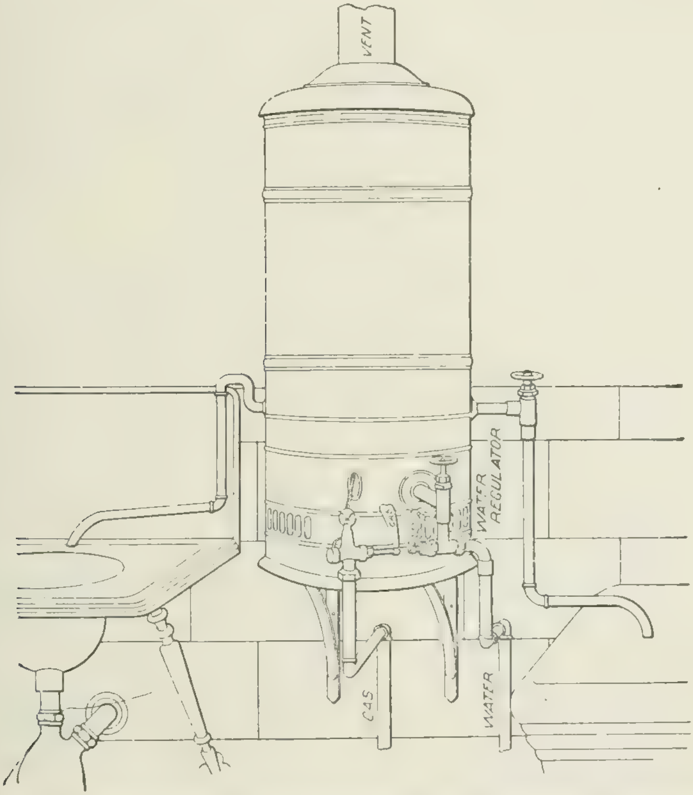


Fig. 92. "Instantaneous" Heater Connected to Gas Supply Pipe. Gasoline is Sometimes Used instead of Gas.

in Fig. 91. It consists of a chamber surrounded by an outer jacket with an air-space between. Circulation pipes, through which the water passes, are hung in the inner chamber, just above a powerful gas-burner placed at the bottom of the heater. Drawing water from the hot faucets lowers the temperature in the reservoir through the cooling influence of the incoming water, and the thermostatic principle is again made to serve in opening the gas-valve until the water is heated to the desired temperature.

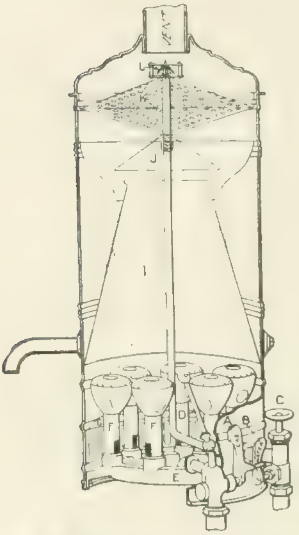


Fig. 93. Sectional View of Gas Heater Shown in Fig. 92.

There are other arrangements consisting essentially of an encased copper coil, above a gas-burner, connected to a standard reservoir at top and bottom. In these, the gas is turned on and regulated by hand as nearly as possible to suit the needs.

Instantaneous water-heaters, operated by gas or gasoline, and placed in proximity to the fixtures served, as shown in Fig. 92, so as to deliver the heated water directly, are in general use where local conditions favor them. These have no storage capacity. A sectional view of Fig. 92 is shown in Fig. 93, in which *A* is the gas-valve; *B*, the water-valve; *D*, the pilot light; *FF*, the burners; *I*, a conical heating ring; *J*, a disc to retard and spread the rising heat; *K*, a perforated copper screen; and *L*, a revolving water distributer. In this heater, the water is exposed directly to the heated air and gases, in addition to its passing over the heated surface of the ring *I*.

Other heaters of this class offer admirable means for the water to take up the heat generated by the gas. All of these special means of heating water—especially those not conforming to the plumber's regular routine—are best understood and judged by a close study of the literature supplied by the makers.

FILTERS

Filters are of two classes. One class is designed to be attached to the end of the faucet or to special connection for drawing directly for use. The other is for use in the general house service, and filters all the water that passes through the main service for whatever purpose. In the former class, sand, free stone, or unglazed potter's clay is used as the filtering medium. Ordinary fillings become foul throughout the mass, and require cleansing or renewing. The clay (unglazed porcelain) of which the Pasteur filter is an example, permits nothing to enter the filtering medium that the pores of this material will strip out. With such, therefore, it is necessary only to remove the tubes and cleanse the surface with which the unfiltered water comes in contact. Any porous filter plate depends for its efficiency upon the minuteness of the pores through which the water passes; and there is a real danger that after a prolonged period of use, these pores may become enlarged by wear from the flowing stream to a size sufficient to allow the passage of bacteria which at the first would have been retained upon the surface of the filter plate. Porous clay filters, however, are exceedingly slow in operation; and it is necessary to employ a multiplicity of tubes, and to collect the filtered water in a reservoir, in order to be able to get enough at once to serve ordinary cooking needs. The filters are supplied with as many tubes as desired, together with the necessary reservoir, all complete excepting connections for the water pipe.

Large filters for service interposition depend upon animal charcoal, beach sand, and coagulating processes—usually the last-mentioned feature in conjunction with one of the other two. A sand filter, for instance, will be made to favor the subsidence of foreign material by the water taking an upward course through the mass of filling, a portion of the water being passed through an alum chamber so as to impregnate the supply sufficient to coagulate impurities which sand alone would allow to pass. When dissolved and carried away, the alum must be replaced. The filling is discarded and new sand put in its place from time to time; and periodic cleansing of the filling is done by reversing the flow of water and flushing out through a waste connection at the bottom. The means of thus keeping the filter in good order are provided for in its construction, in a way to make the cleansing and renewing of the material as easy and convenient as possible.

WATER MOTORS

Water motors for general power purposes, of light nature but requiring comparatively high speed, are made on the rotary plan, a jet impinging on the blades. Others, often used for oscillating fans, operating air-bellows for church organs, etc., have reciprocal motion, the water being handled in a cylinder much as steam is in a reciprocating steam engine. Air-compressors for light duty, operated by water, are made on the reciprocal plan, and also in a way to fill and dump alternately a pair of pivoted buckets, the water pressure expelling the air into an accumulator by filling the bucket with water until it becomes overbalanced, when it falls and trips a waste-valve in the bottom, and at the same time cuts off the supply to one bucket and turns it into the other.

Knowledge of these and kindred devices for producing motion by water-pressure, is not considered a part of the plumber's curriculum; but it is to his interest to learn about them when he can do so without interfering with studies that should take precedence by reason of more immediate importance.

When a pressure tank—the so-called *pneumatic* plan—is used, the supply piping for plumbing fixtures is essentially the same as for street pressure; but when the supply is by gravity, from a tank, new problems present themselves. The type of tank used may in some cases be decided by reasons other than adaptability or simple preference. If of iron, the tank must have a safe-pan to intercept condensation, unless it is insulated from the air, which is difficult and expensive except when the lightness of the metal requires casing for support.

Any shape with flat bottom provides for retaining much sediment that would otherwise flow down with the water. Closed cylindrical tanks, those with merely a pipe-opening to the air, have not even this redeeming feature. Open, rectangular, lead-lined tanks, with loose cover, serve best. An overflow two sizes larger than the supply to tank (never less than 2 inches' diameter) should always be put in near the top. Roof water is sometimes led directly into an attic tank, to avoid pumping. The tank is then divided so that one portion will act as a sort of filter, the water, after subsidence, finding its way into the distributing portion through a screened opening in the partition, some inches above the bottom. This plan requires a large tank, with extraordinary support.

The water is never so well filtered as it may be, if the regular yard cistern with intermediate filter is used; and, all things considered, this is not a plan advisable to follow. The house supply should be taken from a little above the bottom, and well screened to prevent accidental choking. The valve-controlling distribution may be an ordinary stop-cock with an air-pipe carried from immediately below it to above the overflow level, terminating in a position to discharge into the tank, so that air can enter to drain the line; or it may be the regular cistern valve, so arranged, or—which is far better—a hollow stopper valve, with pipe stem extending to above the overflow level, having a chain attached to the stem, and terminating at a convenient point downstairs so that the supply can be stopped at will without going up to the tank. The hollow stem will admit air to the service when the water is off, and there will be no danger of accidental breakage or freezing, as is the case when the necessary relief pipe is carried up outside the tank wall. A standing bath waste fitting can be adapted to admirable service in this capacity; a strainer fitted in the collar of the waste inlet takes the place of the usual screen-hood, and the inlet is just far enough above the bottom to avoid trouble from sediment. The tell-tale pipe should be taken from the bottom of the overflow pipe near the tank, and should discharge where it can easily be observed while pumping is in progress—over the kitchen sink, if the pump is beside the sink. If the closets are to be flushed by valves instead of individual tanks, a separate supply with cut-off should be put in for them.

Pumping into the bottom of the tank, and taking the cold-service branches from the pipe thus used to fill it, should never be practiced. The little difference in head against which the pump must work when pumping over the top, is too small to be considered against the disadvantages of the combined service and pump delivery, even though one line of small pipe is thereby saved. Failure of the single line prohibits service to the fixtures, and pumping into the tank, too; moreover, water that has been pumped is likely to find its way back to the cistern through leaky pump-valves, and there is more trouble in draining both the house pipes and the pump. In placing stop and waste cocks in tank installations, care is necessary to set the right end up, as the water is usually feeding down, instead of up as when direct pressure prevails. Thus, when a cock is set properly, air sometimes enters the waste-hole to cause the line to drain out at some other point—just the reverse of what happens in direct work. However, by bringing the main cold service to the kitchen, and feeding back with the various lines from a manifold, instead of branching out with the cold water on the downward course, the stop-cock work will be about the same as on direct work, after the manifold is reached.

The supplying of hot water to the fixtures should be as direct as possible in all jobs where circulation is desired. Dipping the supply from the top of the reservoir to below the sink level, in order to secure a handy location for the stop-cocks, and ease in taking care of the drain-water, is most certain to interfere with circulation, and not infrequently makes it a matter of impossibility.

The hot-service connection of a tank installation should continue up to and over the tank, as should the main lines of cold service, if convenient, when feeding upward. Also, as there is no street main to give relief, it is good practice to carry a line from the hot-service opening in top of reservoir directly to the tank, and over it, without stop-cocks or branches, so that there will be no ordinary means of closing it. This line will make it impossible to shut off all means of egress for steam and vapor, and may prevent serious accidents otherwise possible.

Tank installations are so often remote from a plumber that every reasonable means should be provided for enabling the users to avoid trouble. A branch from the pump delivery, connecting with the cold service over the reservoir by stop-cock, is permissible, that the reservoir may be filled directly from the pump, by pumping slowly, when the tank or regular supply is out of order. A branch with permanent upright cock-funnel, is often placed on the cold over the reservoir for the same purpose. One may then open the cock, and pour in water with a pail.

The hot service is sometimes brought down from the reservoir, and up behind the sink, for convenience in using the stop-cocks even though circulation is to be employed. In these cases a loop to the attic level is used to induce circulation. Instead of returning from the lavatory or end of the main line, as in other tank jobs and in pressure work, the relief continuation of the hot to the tank is used for the flow of the loop, and a branch is taken from it in the attic and carried back to the bottom pipe of the stove connection. The return of the loop should be larger than the balance—that is, larger than the rising relief from which it is taken. Circulation is dependent upon the difference in temperature of the water in the two lines of the loop; and the large return, by radiation, creates a greater variation of temperature than would be possible in two lines of the same size. It is thus sought to secure sufficient difference in the weight of the two columns to overcome the impediment due to trapping the supply, as stated.

A material auxiliary feature to which success should sometimes be credited in this type of installation, is the skilful arrangement of a tee or Y fitting at the junction with the stove connection. Water being heated in the stove, circulation through the heater is inevitable. To aid the general hot-service circulation, it is then but necessary to divide the work of furnishing water to the heater, between the reservoir connection and the return pipe of the loop. This is done by reducing, at the circulation connection, the flow from the reservoir to the stove, to much less than the capacity of the regular size from that point to the heater. This constriction makes the reservoir feed inadequate to supply the demand of the heater; and the deficit is drawn from the circulation loop, thus keeping the water in motion therein—which is the end in view. If a Y fitting is used, the circulation should attach to the branch, so that its flow will change direction only 45 degrees. If a tee fitting is used, the constriction should be in the branch, and the circulation connected at the end of the tee, so that its flow will not change course at all in joining the feed from the reservoir.

The means of turning the sediment pipe on and off should always be a ground-key cock so that one can see at a glance whether it is on or off, as accidental emptying of the reservoir is dangerous. Another reason for using cocks is that the shearing action of the core, when turning, will cut off a piece of lint or other foreign matter that would not permit a compression stop to close tight. Whether a cock has closed tight, is not observable; and the whole supply in a tank job may in this way be lost without warning, leaving the heater dry. Unknown waste through the sediment cock retards heating. The failure of hot faucets to close tightly will waste water as fast as it is heated. Hot faucets should have washers adapted to withstand heat, in order to avoid frequent repairing.

Where lime or other deposits choke the water-back and connections as ordinarily installed, both the annoyance and the danger may be avoided by following the plan shown in Fig. 94, in which the water is heated by water by conduction through a coil in the reservoir. The water-back is connected to the coil; and an expansion tank, piped as shown, is provided to take care of the expansion of the water in the primary heater or water-back. Distilled water is used in the back to avoid incrustation of the back and connections. *C* is the tank, which must be filled to above the flow connection. *G* is tank return; *D*, the drain to water-back and connections; *E*, a sediment cock on the reservoir proper. The flow from upper water-back connection to expansion tank should be at least one size less than either the coil in the reservoir or its connections.

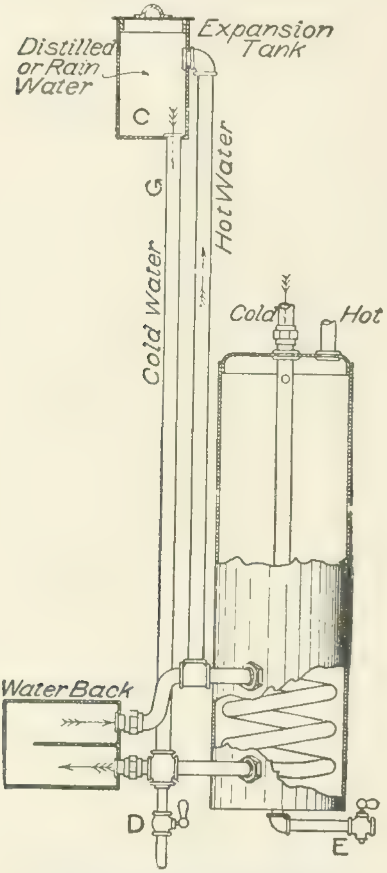


Fig. 94. Reservoir Heated by Hot-Water Coil, Connected to Water Back, Avoiding Choking from Lime or Other Deposits.

When cost is not the desideratum, direct-pressure plumbing is generally better if a tank is used, even though the initial pressure is ample and not excessive. The pressure on the fixtures is then always constant, and also moderate unless the building is very high. This point is important where the city pressure is sufficient for fire purposes, or when the pressure is carried abnormally high only during the need for fire purposes and then reduced. A high-pressure line feeding the house tank and controlled by a ball-cock, permits valves of simpler mechanism and lighter pipe and fittings, and reduces water-hammer, etc. Moreover, much foreign matter carried in suspension is got rid of, subsidence improving the water and reducing the wear and tear on valves and washers to a minimum.

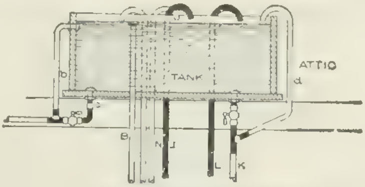


Fig. 95. Essential Connections of a House Tank.

Fig. 95 shows the essential connections of a house tank. *B* is the supply to tank. A ball-cock is used when city pressure supplies the tank; *C* is the drain-pipe, and *B* the overflow. *K* is the cold service to fixtures; and *d* the air-pipe enabling the line to drain when the cock is turned off. The cold-service connection rises above any possible sediment level in the tank. *J*, *L*, *N*, etc., are extensions of the hot and cold fixture lines.

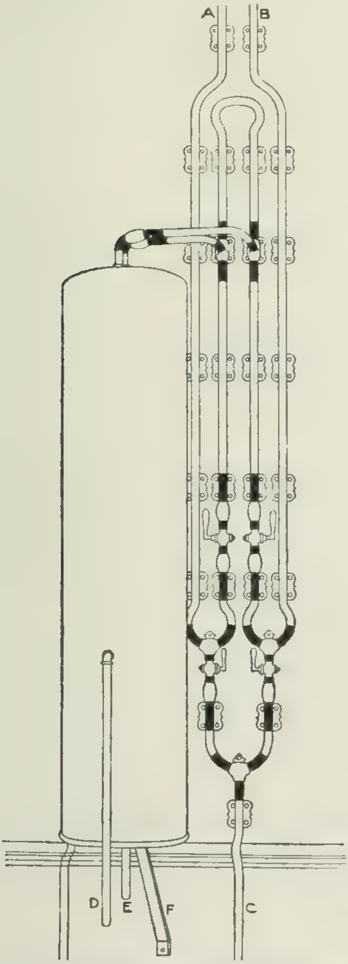


Fig. 96. Distributing Lines of Lead Pipe for a Tank Installation.

Fig. 96 shows the distributing lines of a lead-supply tank installation. *A* is the pipe leading from the tank to the reservoir, the cold for bathroom being branched from it above. *B* is the main hot service. *D* and *E* are range connections. *F* is a brace supporting the ring under the reservoir. The main stops are within reach from the floor. *C* supplies a hall lavatory, and also acts as a drain for the main lines. The arrangement permits supplying either hot or cold water to the little hall lavatory; and a cock at the lowest point in *C* enables the whole combination to drain through it when necessary.

By reason of addition of fixtures, incrustation, or other sufficient cause, supplies sometimes fail to give water rapidly enough. This can be remedied by attaching a closed cylinder, and feeding from it. The pressure will fill the cylinder more or less when water is not being drawn, so that it will flow in abundance when a faucet or valve is opened.

If the regular supply is dropped into a cylinder, a separate feed pipe is necessary. If the fixture line is large enough, the cylinder may be placed at the upper end, and a check-valve below the lowest fixture to retain what enters the cylinder. Then, when a faucet is opened, the cylinder furnishes the water until it is exhausted or the street pressure supplements or overcomes the downward flow.

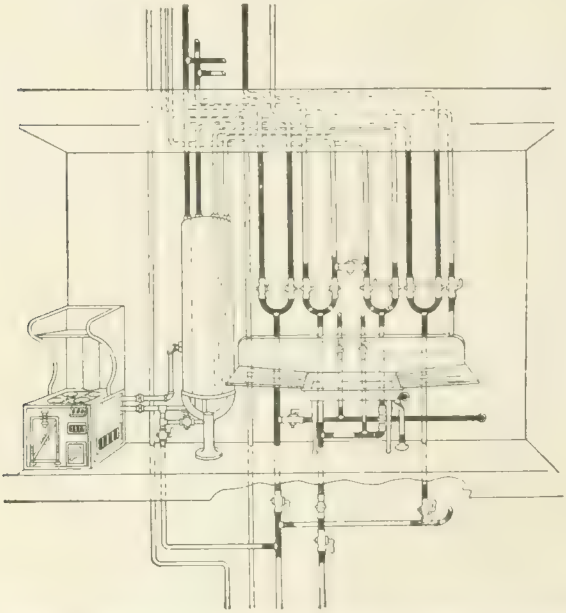
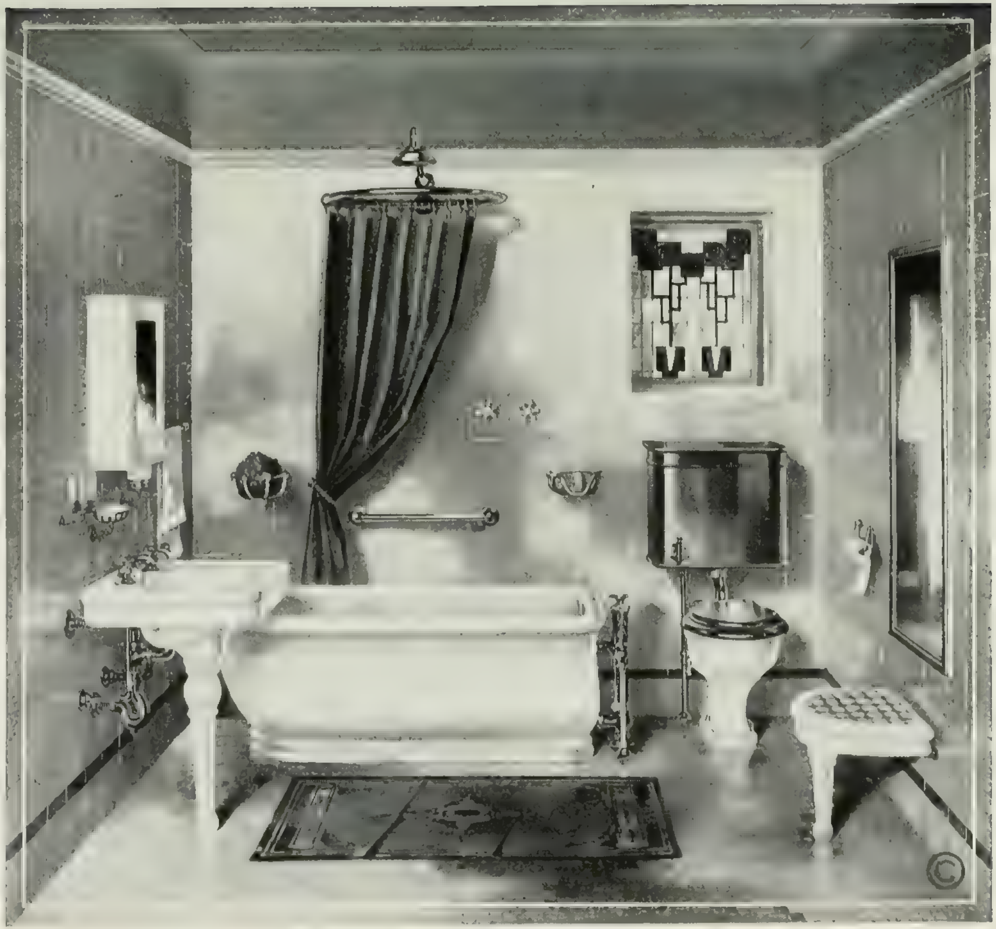


Fig 97. Double-Reservoir Installation for Heating Combined Direct and Tank Supply. Reservoir Consists of Two Concentric Cylinders, Outer One (Direct) being Connected to Water-Back, and Inner One Heated by Conduction.

Where the street pressure is not sufficient to reach upper floors, trouble is often experienced in pumping to the tank, on account of the service being too small to fill the cylinder of the pump at ordinary speed. This can be overcome by placing a pocket or sort of air-chamber in the service, and connecting the pump suction to it. The influx of water to the pocket is constant, and the suction of the pump intermittent; hence the full, unchecked capacity of the service pipe is available to the pump. The air-chamber feature permits the water to leave the pocket easily. It is proper to place a check-valve on the house side of pump connection, to avoid annoyance from air when faucets used directly are opened.



BATH-ROOM OF MEDIUM SIZE
Notice Arrangement of Fixtures for Limited Space
James B. Clow & Sons, Chicago

Another problem of inadequate street pressure where part of the house is supplied from a tank, is the heating of the water of both systems. Only large hotel ranges maintain two fires; and there is not ordinarily room for two heaters in one firebox without interfering with the fire or with the baking properties of the cooker; and mixing the supplies is prohibitive. The difficulty has been overcome in two ways. In one, a double reservoir is used, the low pressure (water from the tank) being turned into the inner one, which is concentric with the outer. A job of this kind is illustrated in Fig. 97. The room required for one reservoir is thus saved, and no extra water-back or secondary heat is necessary. One set only of range heater connections are made—to the outer reservoir. The inner reservoir being entirely encased by the water of the outer one, the heating of the water in the inner one is accomplished by conduction only. The range heater might be connected to the inner reservoir; but the surface for conduction would be the same, and much heat, received by conduction only, would be radiated from the walls of the outer reservoir. The low pressure might also be connected to the outer reservoir; but greater care in providing against the possibility of the inner one collapsing would be necessary, as it is or should be made of copper. In double-reservoir jobs, a connection, with check-valve, from the street cold to the tank cold, is made at the reservoir. In this way, if the tank should become empty, the street pressure opens the check-valve without attention, and keeps the inner reservoir filled, and of course supplies automatically any fixture on the high-pressure system that the street pressure will reach.

A second plan of heating the water of both systems, also by conduction, is to use two independent reservoirs. The system requiring the greatest amount of hot water is given a direct connection to the heater, except that a secondary heater for warming the water of the other system by water is interposed in the upper pipe of the connections leading to the firebox. The secondary heater has a series of channels or cells, all connecting and pressure-tight and provided with openings for pipe connection. The water of one reservoir is connected to these openings in the secondary heater, just the same as though it were in the firebox; and the water of one system is in that way heated by conduction, by circulation of heated water of the other passing from the range heater to the reservoir.

The third method of providing *double-boiler* service is shown in Fig. 98. Referring to the engraving, *A* is a $1\frac{1}{4}$-inch pipe, leading directly to the tank, and bending over the top. It is connected to a pump in the basement. *B* is the main supply from the street, to which pipe *A* is connected at a lower point. No. 2 is a check-valve placed in the main street supply for the purpose of preventing the pump from drawing water from the street-pressure reservoir while pumping water into the tank in the attic. This might occur for various reasons if a check-valve is not used, and would certainly result in case the pump should be operated while the street supply was shut off. Check-valve No. 2 also prevents the tank water from going into the street pipe when both systems are working under high pressure. In practice, a drain-cock should be placed in pipe *B* above check No. 2. *C* is the main cold supply, leading directly from the tank to the kitchen, without branches to fixtures at any point. It connects above check-valve 3 to a pipe leading to the tank-pressure reservoir. From the lower end of check 3, a pipe leads over to the main cold supply *B*. The superior pressure of the tank system keeps check 3 closed, so that water cannot enter the tank system or reservoir from the street while there is pressure upon it from the tank supply. However, immediately upon the tank becoming empty, or its pressure shut off at cock No. 9, the pressure falls in the tank-system pipes until the pressure is inferior to the street pressure, and check No. 3 opens upward and allows the street pressure to keep the tank-pressure reservoir filled. Otherwise trouble might possibly result, but it is not so probable as in jobs having one reservoir within the other. This check admits of both reservoirs filling without having water in the tank when the job is first started; and although it is a minor point to speak of, it is best to be prepared for accidents.

The main cold supply from the tank is controlled by stop-cock No. 9. Just below the cock a small pipe is branched in, and carried up and curved over the top of the tank, to admit air when it is desired to drain the pipe. *D* acts as a drain to the hot-water pipes of both reservoirs. The sediment pipes of the reservoirs are also connected to it.

To aid the reader in tracing the different pipes easily, all the hot-water pipes are represented by heavy black lines, and the cold-water pipes by double parallel lines. C^1 is the cold supply to tank-pressure reservoir; C^2, tank supply, cold water, to fixtures on the second and third floors; C^3, cold supply to street pressure reservoir; and C^4, cold supply from street pressure to fixtures on the first floor. *FF* are hot and cold faucets at the kitchen sink, the hot being on the left side. *H* is the main hot supply of the tank system; H^1, hot supply from the tank reservoir to the fixtures on the second and third floors; H^2, main hot supply from the street-pressure reservoir; and H^3, hot supply from the street reservoir to the fixtures on the first floor.

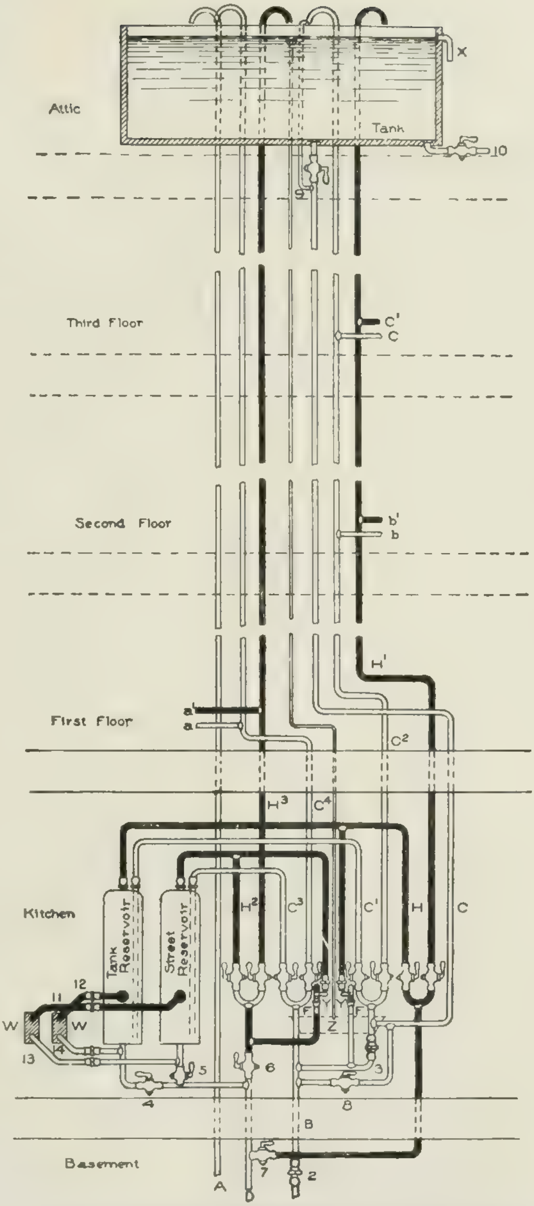


Fig. 98. Double-Reservoir Installation for Heating Combined Direct and Tank Supply. Two Independent Reservoirs, Each Connected to a Water-Back.

It will be noticed that each of the supplies has been carried up as high as the top of the tank, and curved at the end so that they will discharge into it, which, in the case of hot supplies, might occur from steaming. The extension of the fixture supplies to the top of the tank with ends left open, insures that they will drain themselves when the water is shut off; and also cushions the pressure when the faucets are turned off quickly, the same as air-chambers do on direct-pressure systems.

The hot and cold supplies from the street reservoir might be left off at the point where the branches are made on the first floor, without causing any material difference in the working. In that case, however, there would be no vapor relief for the reservoir through the hot-water pipe; and when the cocks were shut off, none of the pipe would drain unless the faucets were opened upstairs. As it is, the main line will drain whether the faucets are open or not; and there is also the advantage of the air-cushion and relief as well.

Of the cocks over the kitchen sink, only those which have waste tubes indicated on the pipes leading to fixtures on the upper floors are stop and waste cocks. The others are plain stops which prevent any chance of causing them to waste continually by some error in using them. Stops and waste would be of little value on the lines above the sink which lead direct to the reservoirs, because it is not particularly desirable to drain any of the pipe between the cocks and the reservoirs while the cocks mentioned are shut off.

The branches aa^1, bb^1, and cc^1, are of $\frac{5}{8}$-inch pipe, and supply fixtures on the first floor from the street pressure, and on the second and third floors from the tank pressure. W and W represent water-backs, both of which are in the same firebox of the range. One of them is connected to the tank reservoir by means of circulating pipes 12 and 14, while the other is connected to the street reservoir by pipes 11 and 13. The sediment pipes of the reservoirs are controlled by cocks 4 and 5. Both of the sediment pipes discharge into the general drain-pipe D. The overflow pipe of the tank is indicated by X. Y and Y are vacuum valves situated over the kitchen sink. They communicate with the reservoirs through branches from the main hot supplies.

By referring to the engraving, the reader will see that there is no way to cut off communication between the reservoirs and the vacuum valves. With the valves placed at the sink as shown, the weight of the water in the vertical pipe above the valves must be overcome before air will enter the reservoirs. If desired, the valves may be placed in the heads of the reservoirs, and a pipe carried over to the sink to take care of the drippings. In this style of double-boiler work, vacuum valves are not so important as they are in systems having one reservoir within the other, because the reservoirs here described work under about the same conditions as those in ordinary single-reservoir jobs. The tell-tale pipe discharges over the kitchen sink, and is indicated by *Z*. Cock 6 is to drain the hot-water pipe from the street reservoir, and cock 7 drains the hot pipe from the tank reservoir.

Cock 8 is placed in a connection where, when turned on, it allows the tank pressure to by-pass check valve No. 3. By this means, both systems may be worked under high-pressure duty when the street pressure is off. In a case where the street pressure is constant for the fixtures on the first floor, but does not reach the second, cock 8 will seldom have to be used, and it should then be of a type having a removable handle.

One point gained by bringing the pipes down and up, as shown by the loops over the sink, is, that every stop can be reached from the floor without the aid of a ladder. The fixtures on the upper floors can be shut off without interfering with the supply to kitchen sink or other fixtures that may happen to be on the lower floors.

The sizes of the pipes shown in this installation, which have not already been given, are as follows: *B* and *C*, ¾-inch; C^1, C^2, C^3, C^4, ⅝-inch; *D*, ¾-inch; *FF*, ⅝-inch; *H*, H^1, H^2, H^3, ⅝-inch; *X*, 1½-inch; *YY*, ½-inch; *Z*, ⅜-inch; 11 and 12, 1-inch; 13 and 14, ¾-inch. Cocks 4 and 5 are ¾-inch; 6, 7, and 8, ⅝-inch; and 10, 1¼-inch.

Plumbers habitually having this type of work to contend with—New Yorkers, for instance become ultra-skilful in meeting the difficulties presented by variable pressure. The range of variation may cover the second floor of one building and the third of another, according to elevation. The fixtures on the floor with intermittent street supply can be placed wholly on the tank system, only at the expense of pumping all the water used in them. To take advantage of the street pressure reaching those fixtures at certain hours, four cocks are arranged so that one handle will turn all of them at once—two closing the tank hot and cold supply from the fixtures on that floor, and two admitting instead the street-pressure hot and cold.

There are many interesting features in piping water for municipal service, but it is not in the province of this work to consider them.

GAS PIPING

The work of piping for gas is so closely allied to that of plumbing, since iron pipe has come into general use, that a brief notice of this branch is not out of place in connection with matters pertaining to plumbing. Coal gas is only about one-half the specific weight of air. The weight of natural gas is somewhat less than that of coal gas. The distribution of pressures which prevails in a closed system—the pressure of the fluid being equal at every point—should not be lost sight of in considering the ordinary method of distributing gas over a city or through a building in closed pipes. Although it would be true that in an open vessel the pressure of illuminating gas would by reason of its low specific gravity be greater at the top of the vessel than at the bottom, this is not the case in a closed system in which a fixed pressure is maintained.

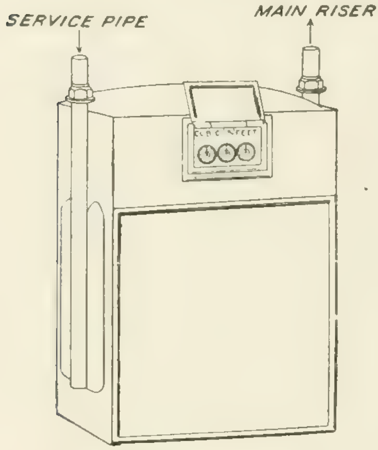


Fig. 99. "Dry" Gas Meter.

The most economical pressure at which to consume gas is five-tenths of an inch water pressure. As no town is strictly level, and the friction of the pipe requires some head of pressure to overcome it, the pressure in the mains is carried above the point at which the best results are obtained. This is generally counteracted by not turning on the full amount at the burner. In towns varying greatly in the level of different portions, it is economy to use an automatic governor to reduce the pressure. This is true of exceedingly tall buildings, too. But in the tall building, one governor for the whole is not enough; the supply to the upper floors should be controlled by a governor situated on one of the upper floors.

Large pipe should not be notched into joists in the middle of their length; it weakens the joists. All pipes should be laid with a decline, toward the meter when possible, otherwise in such a way that they will drain toward a fixture or drip. The meter should be placed in a position easily accessible, and where it may be read without the use of an artificial light. It is connected in the house main on the street side of the first branch. A *dry* meter—the kind now almost universally employed—is shown in Fig. 99.

Different meters vary but little in the arrangement of the dials. In large meters, there are as many as five or more dials; but those used for dwelling houses usually have but three. Fig. 100 shows the common form of index in a dry meter. The small index hand *D*, on the upper dial, is not taken into consideration when reading the meter, but is used merely for testing. The three dials, which record the consumption of gas, are marked *A*, *B*, and *C*; and in each, a complete revolution of the index hand denotes 1,000, 10,000, and 100,000 cubic feet, respectively. The index hands do not move in the same direction. When the hands are pointing upward, *A* and *C* move from left to right, while *B* moves in the opposite direction. Annex two cyphers at the right of the figures indicated when taking the statement of a meter. The left-hand index shown in Fig 100 reads 48,700. Suppose, after being used for a time, the hands should have the positions shown in the right-hand dial. This would read 64,900; and the amount of gas used during the interval would equal the difference in the readings: 64,900 — 48,700 = 16,200 cubic feet. Meters so invariably register in favor of the consumer after being in use only a few weeks, that the companies are by law permitted to set them 2 per cent fast when new.

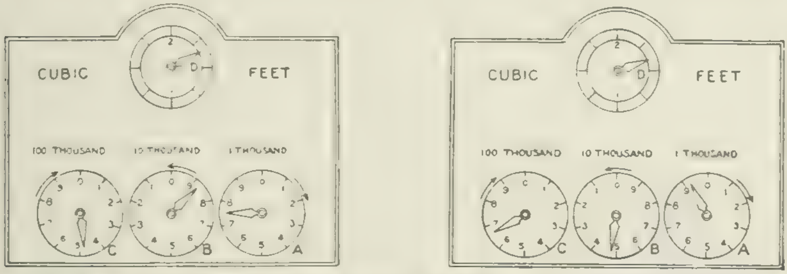


Fig. 100. Common Form of Index on "Dry" Gas Meter. Two Readings are Shown.

The route chosen for gas pipes should be the warmest consistent with convenience and economy. Coal gas will freeze—that is, the moisture in it will, in severe weather, form a network of frost that checks or stops the flow. Coal gas and natural gas are practically fixed. There is little trouble from condensation, even from coal gas, after it reaches the residence. There is sufficient reason, however, to incline the pipe and to avoid trapping any portion so that it will not drain. If a pipe runs through a cold place, a drip should be put in at some convenient point where it can be emptied if necessary. No offsets should be made in a way to favor choking the pipe by the products of corrosion falling down vertical parts. No fixture or bracket opening should be less than ⅜-inch; no rising main less than ¾-inch All openings for fixtures should have straight threads, and the pipe or fittings should be well secured, perpendicular to the wall passed through, so that they will not wobble, push in, or pull out. Ceiling drops should be cemented in the joint at the line, so that they will not unscrew when the cap is removed or a fixture taken down.

The making of intelligent working diagrams for gas or water fitting, is not difficult. Though important, comparatively few have given it due attention. When plans are accurate, the usual work of making figures to show what length the pipes are, may be dispensed with by employing self-measuring ruled sheets in conjunction with the method of diagramming here described. Diagramming systematically and with all lines approximately proportional in length, saves time in distributing the pipe. There is no wondering whether a piece runs down or up, or as to which room a bracket light looks into, or whether a piece of pipe belongs in a horizontal or in a vertical position. A properly made diagram indicates these points clearly, and also what pieces belong in the same plane. There should never be any confusion as to which pieces have been cut and which not, when getting out the pipe. Symbols can be made to show what pieces have been cut and what size they are. The symbols found by practice to answer this purpose best, are as follows: When a ¼-inch piece is cut, a common check mark is put *beside* the line on the diagram, showing that it is ¼ inch and has been cut. For a ⅜-inch piece, a short, straight mark like the letter I, placed *across* the line, is used. For a ½-inch piece, two connected marks like V are made *across* the line. For ¾-inch pieces, three connected marks, like the capital N, are made *across* the line. For 1-inch pieces, four connected marks, like the capital letter M, are used *across* the line. For 1¼-inch

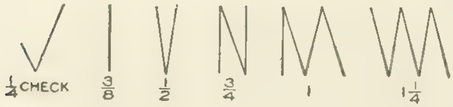


Fig. 101.Symbols Used in Piping Diagrams.

pieces, five connected marks, like the capital W with one extra leg, are used. Each short, straight mark represents a quarter-inch in the diameter of the pipe, except in the case of ⅜-inch pipe For nipples that are too short to put the symbols on, draw a waved arrow from the nipple, and put the symbol upon it. Fig. 101 shows the symbols described, with corresponding sizes of pipe marked beneath them.

In reading plans of buildings, it is usual to have the front of the building, as represented by the plans, next to the person. Plans represent horizontal sections at the elevations designated; while elevations show the altitude of one floor above the other, etc. The plans of the different floors of a building are usually drawn side by side, with the outside face of the front wall on a line. By this means, a straight edge laid across the plans from side to side, will show which partitions are in line with one another. One can judge with the eye, on the cross-partitions, accurately enough to give a good idea of the relative position of the rooms on different floors, one way; but to locate the partitions running from front to back, it is necessary to measure from the wall on the plans of the different floors. House plans are almost always drawn to ¼-inch scale. In gasfitting diagrams, all sizes of pipe are represented by single or skeleton lines, because the pipes are small.

Now, assuming the plans to be marked for gas, center the rooms, and chalk all wall openings. Then proceed to diagram the lines representing the pipe, making them as nearly proportional to the length of pipe as can easily be done with pocket-rule and pencil, say to ¼-inch scale.

Represent all vertical pipes by diagonal lines parallel to one another, whether they be bracket pipes, risers, or offsets in the line. Never represent a horizontal pipe by a diagonal line. Every vertical pipe which *falls below* the horizontal pipe to which it is connected, should be drawn *toward the front* of the plan at an angle of 45 degrees to the *left.* Every vertical pipe which *rises above* the horizontal pipe to which it is connected, should be drawn *away from the front* of the plan, at an angle of 45 degrees to the *right.* Represent all horizontal pipes by parallel lines perpendicular either to front or to side wall. When the run of pipe is from front to back, the parallel lines should be perpendicular to the front wall of the building. When the run is from side to side, the parallel lines should be perpendicular to the side wall of the building. Any line in the diagram that is perpendicular to any other line of the diagram may then be taken to represent a horizontal pipe. Any number of lines representing horizontal pipe and all joined together, are thus indicated to be in the same horizontal plane. Any single line or system of lines representing horizontal pipe, but separated from the others by a diagonal line, is therefore in a different horizontal plane. For instance, the second-floor riser, 10 feet 3 inches long, shown in the diagram, Fig. 102, connects the horizontal pipe under the second floor with that under the third floor. These pipes are in different planes, one set being 10 feet 3 inches above the other.

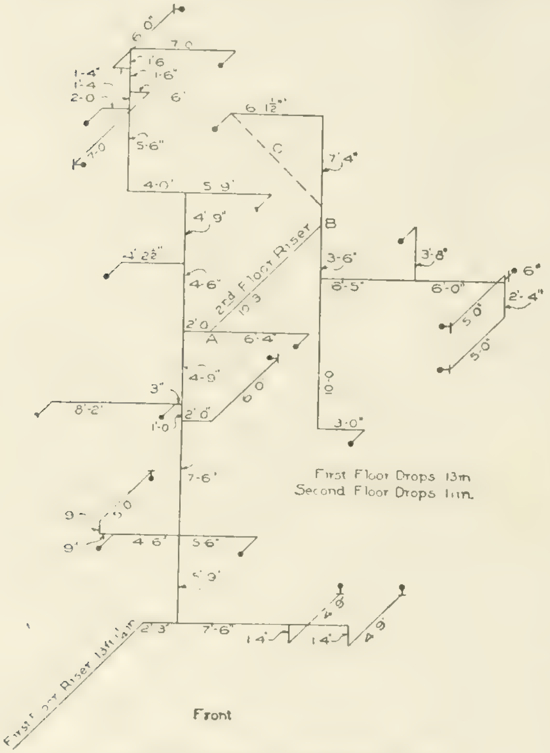


Fig. 102. Diagram of Gaspipe Lines.

There is one exception to the rule concerning diagonal lines. Several feet of pipe can often be saved by cutting across, instead of making an angle with, the pipe. To do this without danger of confusing one as to whether the diagonal piece is intended for vertical pipe or for a diagonal piece in the horizontal plane, make such lines *dotted* instead of *solid*, as shown at *C*, Fig. 102.

To indicate the direction in which bracket openings look, by the way in which they are drawn, eight skeleton diagrams of bracket pipes, showing how the direction of bracket openings would be indicated for the four walls of a square room, are shown in Fig. 103. *A*, *B*, *C*, and

D show that the pipes are vertical and run up from the floor below. *A* looking into the room from the front wall, *B* from the rear, *C* from the left side wall, and *D* from the right side wall. In accordance with plan drawing, the short lines representing the ears and nozzle of the drop-ells are made in plan position with dots at the ends to represent caps. The ears of the fitting, drawn in front of the outlet, show that the fitting looks to the rear; ears behind the outlet show that it looks to the front; at the left of it, that it looks to the right; and to the right of it, that the fitting looks to the left.

A^1, B^1, C^1, and D^1 show fittings that look in the same direction as those shown by *A*, *B*, *C*, *D* of the same figure, but are on pipes that run down from the horizontal pipe. By varying the positions of the marks representing the drop fittings to suit, the diagram can be made to indicate openings pointing in any direction desired.

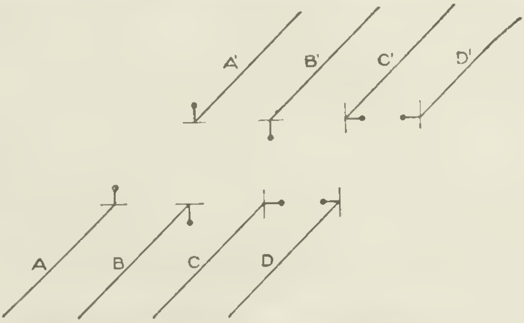


Fig. 13. Skeleton Diagrams of Bracket Pipes.

All large risers should be exposed to view; and it is desirable to keep all piping accessible as far as possible, so that it may be easily reached for repairs if necessary. When it is necessary to trap a pipe, a drip with a drain-cock must be put in; but this should always be avoided under floors or in other inaccessible places. Where possible, it is better to carry up a main riser near the center of the building, as the distributing pipes will then average smaller, the timbers will not require so much cutting, and the flow of gas will be more uniform throughout.

Unless otherwise directed, outlets for brackets should be placed 5½ feet from the floor, except in the case of hallways and bathrooms, where it is customary to place them 6 feet or more from the floor. Upright pipes should be plumb, so that nipples which project through the walls will be level; the nipples should not project more than ¾ inch from the face of the plastering. Laths and plaster together are usually about ¾ inch thick, so that the nipples should project about 1½ inches from the face of the studding. *Drop-* or *side-ells* are used where possible for bracket openings. Gas pipes should never be placed on the bottom of floor timbers that are to be lathed and plastered, because they are inaccessible in case of leakage or alterations. Fig. 104 illustrates some lines of gaspipe in a frame building, from which may be gleaned graphic ideas of how to fasten pipe securely in place.

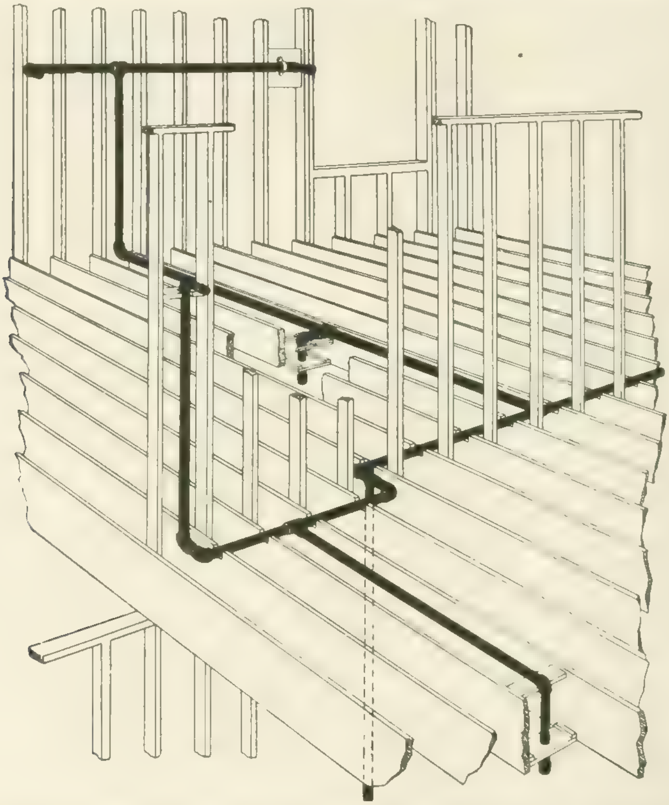


Fig. 104. Lines of Gaspipe in Frame Building Showing How Pipes are Secured in Place

Coal gas, and natural gas of some locations, has a strong odor that betrays leakage. Some natural gas is devoid of odor, in which case leakage is very dangerous, as there is no way quickly to detect its presence. For natural gas work, 10 pounds' air-pressure should fail to develop the slightest leak in the pipe, although the street pressure is usually even less than eight ounces. For lighting gas, the street pressure is seldom over 18 tenths water-pressure, and a 5-pound test is ample. These tests should be made with a mercury gauge, 2 inches height of column being considered as one pound pressure. A job may be considered tight when the mercury column not only does not drop, but does not even get flat at the top in from fifteen to twenty minutes' trial.

Every gas company has rules as to the number of lights allowed to be supplied from each size pipe, and the relative lengths of pipe permitted of each size. The following table gives sizes of gas pipes for different numbers of burners and lengths of runs, as usually installed:

TABLE IV

Maximum Run and Number of Burners for Gas Pipes

Size of Pipe	Greatest Length of Run, Feet	Greatest Number of Burners to be Supplied
⅜ inch	20 feet	2
½ "	30 "	4
¾ "	50 "	15
1 "	70 "	25
1¼ inches	100 "	40
1½ "	150 "	70
2 "	200 "	140
2½ "	300 "	225
3 "	400 "	300
4 "	500 "	500

No restrictions are observed in selecting fixtures for coal or natural gas. Coal gas carries enough carbon with it to produce a lighting flame when burned at the ordinary flame temperature. When the jet is lighted, the hydrogen is consumed in the lower part of the flame, producing sufficient heat to render incandescent the minute particles of carbon carried by it. The hydrogen, in the process of combustion, combines with the oxygen of the air, forming an invisible vapor of water, while the carbon unites with the oxygen, forming carbonic acid, or is set free as soot.

Various causes tend to render combustion incomplete. There may be excessive pressure of gas, lack of air, or defective burners. An excess of pressure at the burners causes a reduction of the amount of illumination; on the other hand, if the pressure is insufficient, the heat of the flame will not raise the carbon to a white heat, and the result will be a smoky flame. It therefore follows that for every burner there is a certain pressure (usually $\frac{5}{10}$ of an inch water-pressure before mentioned) and a certain corresponding flow of gas, which will cause the brightest illumination.

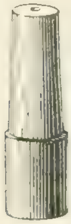


Fig. 105. Single-Jet Burner.

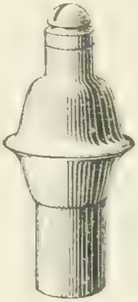


Fig. 106. Bat's-Wing or Slit Burner.

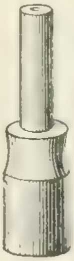


Fig. 107. Union-Jet or Fish-Tail Burner.

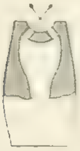


Fig. 108. Vertical Section of Union-Jet Burner.

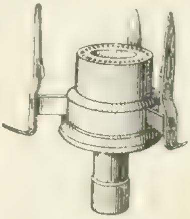


Fig. 109. Argand Burner.

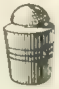


Fig. 110. Lava Tip for Bat's-Wing Burner.

There are a great variety of burners upon the market, among which the single-jet, bat's-wing, fish-tail, Argand, regenerative, and incandescent burners are the principal types.

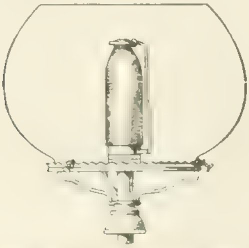


Fig. 111. Gas Burner with Globe and Incandescent Mantle.

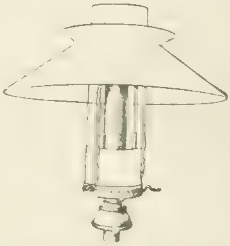


Fig. 112. Mantle Burner with Chimney and Shade.

The *single-jet* burner, Fig. 105, is the simplest kind, having but one small hole from which the gas issues. It is suitable only where a very small flame is required.

The *bat's-wing* or *slit* burner, Fig. 106, has a hemispherical tip with a narrow vertical slit from which the gas spreads out in a thin, flat sheet, giving a wide and rather low flame resembling in shape the wing of a bat, from which it is named.

The *union-jet* or *fish-tail* burner, Fig. 107, consists of a flat tip slightly depressed or concaved in the center, with two small holes drilled, as shown in Fig 108. Two jets of equal size issue from these holes, and, by impinging upon each other, produce, at right angles to the alignment of the holes, a flat flame longer and narrower in shape than the bat's-wing, and not unlike the tail of a fish. Neither of these burners requires a chimney, but the flames are usually encased with glass globes. They are not well suited for use with globes, however, since when one of the jets becomes choked, as it frequently does, the other is likely to crack the glass.

The *Argand* burner, Fig. 109, consists of a hollow ring of metal or lava, connected with the gas tube, and perforated on its upper surface with a series of fine holes, from which the gas issues, forming a round flame. This burner requires a glass or mica chimney. As an intense heat of combustion tends to increase the brilliancy of the flame, it is desirable that the burner tips shall be of a material that will cool the flame as little as possible. On this account, metal tips are inferior to those made of some non-conducting material, such as lava, adamant, enamel, etc. Metal tips are also objectionable because they corrode rapidly, and thus obstruct the passage of the gas. Fig. 110 shows a lava tip for a bat's-wing burner. Burner tips should be cleaned occasionally, but care should be taken not to enlarge the holes.

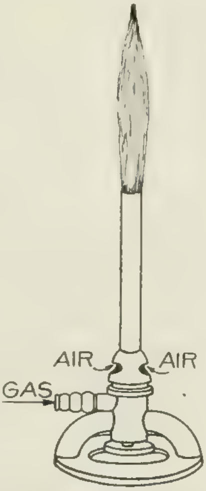


Fig. 113. A Bunsen Burner.

By introducing the Bunsen principle, *incandescent* burners give good service with coal gas. In the incandescent burner, the heat of the flame is applied in raising to incandescence some foreign material, such as a basket of magnesium or platinum wires, or a funnel-shaped asbestos wick, or a mantle treated with sulphate of zirconium and other chemical compounds. A burner of this kind is shown in Fig. 111, in which the mantle can be seen supported over the gas flame by a wire at the side. Fig. 112 shows another form of this burner, in which a chimney and shade are used in place of a globe. Burners of this kind give a very brilliant white light when used with natural or water gas. Natural gases and the so-called water gas are deficient in carbon; and, when they are used for lighting

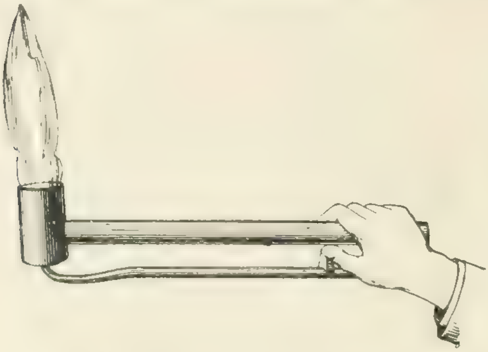


Fig. 114. Gas Burner for Brazing.

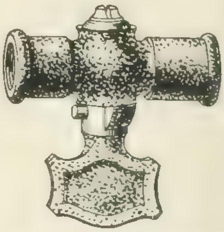


Fig. 115. Single Gas-Cock with Stop-Pin.

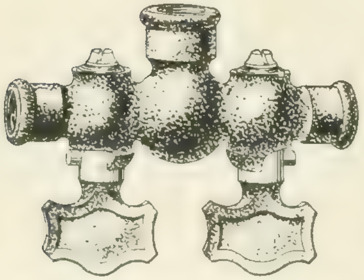


Fig. 116. Double Gas Cock with Stop-Pins.

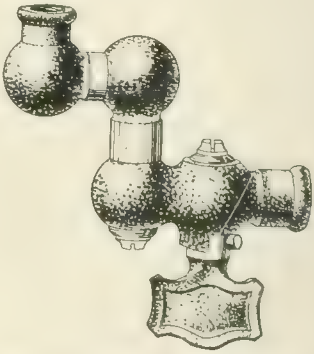


Fig. 117. Elbow Gas Cock with Stop-Pin.

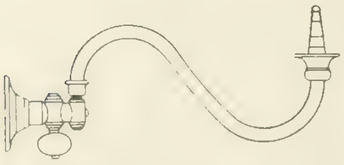


Fig. 118. Common Form of Gas-Bracket.

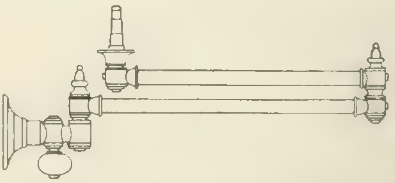
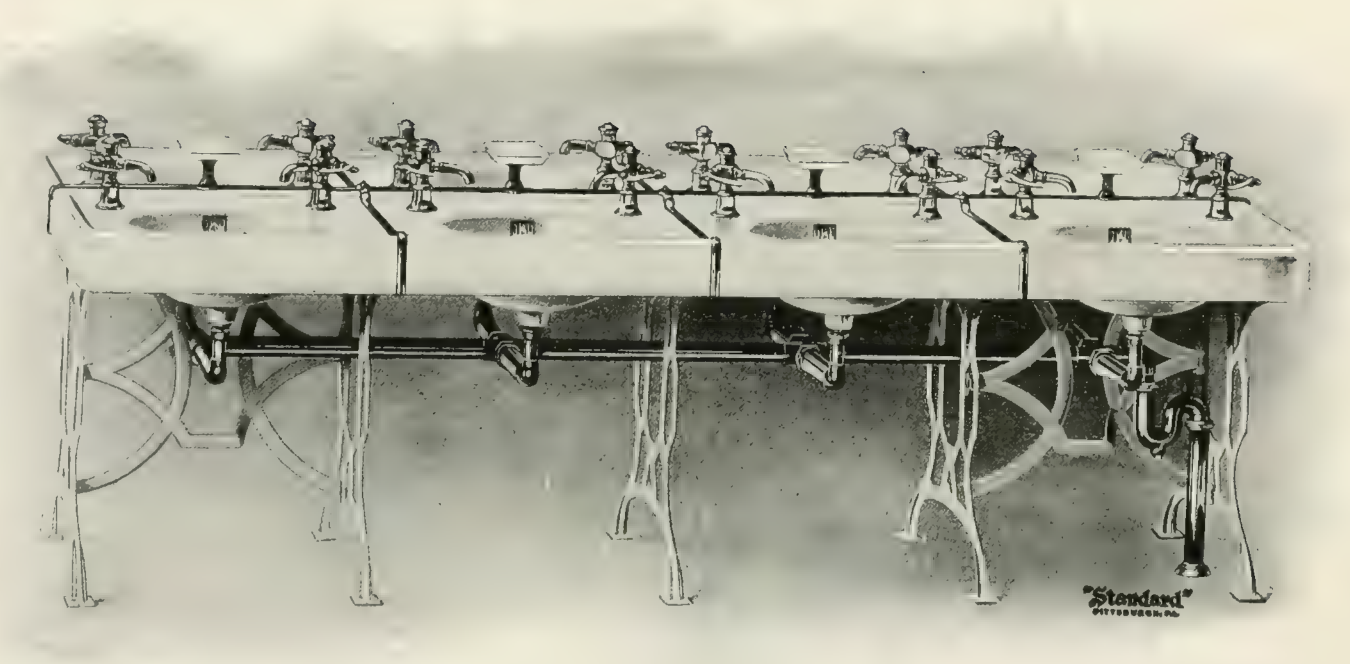


Fig. 119. Two Swing Extension Gas Bracket.



PORCELAIN ENAMELED PANDORA DESIGN DOUBLE SECTIONAL LAVATORY
Standard Sanitary Mfg. Co.

purposes, the light is produced by a burner with a mantle brought to a state of incandescence by the heat of the flame. The mantle, however, is very fragile, and is likely to lose its property of incandescence when exposed to an atmosphere containing much dust.

The *Bunsen burner*, shown in Fig. 113, is a form much used for laboratory work. It burns with a bluish flame, and gives an intense heat without smoke or soot. The gas, before ignition, is mixed with a certain quantity of air, the proportions of gas and air being regulated by the thumb-screw at the bottom, and by screwing the outer tube up or down, thus admitting a greater or less quantity of air at the openings indicated by the arrows. This same principle is utilized in a burner for brazing, the general form of which is shown in Fig. 114. A flame of this kind will easily melt brass in the open air.

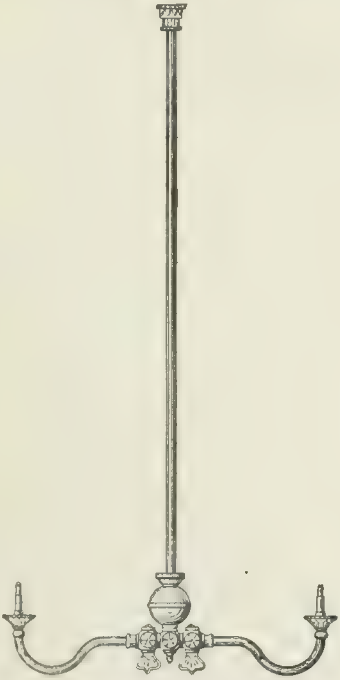


Fig. 120. Plain Type of Two-Burner Gasolier

It is of great importance that gas keys on fixtures should be perfectly tight. It is rare to find a house piped for gas where the pressure test could be successfully applied without first removing the fixtures, as the joints of folding brackets, extension pendants, stop-cocks, etc., are usually found to leak more than the piping. The old-fashioned all-around cock without check-pin should never be allowed under any conditions; only those provided with stop-pins are safe. Various forms of cocks with stop-pins are shown in Figs. 115, 116, and 117. All key joints should be examined and tightened up occasionally to prevent them becoming seriously loose and leaky.

Poor illumination is frequently caused by ill-designed or poorly constructed brackets or gasoliers. Gas fixtures, almost without exception, are designed solely from an artistic standpoint, without due regard to the proper conditions for obtaining the best illumination.

Fixtures having too many scrolls or spirals may, in the case of imperfectly purified gas, accumulate a large amount of a tarry deposit, which, in time, hardens and obstructs the passages. Another fault is the use of very small tubing for the fixtures. Common forms of brackets are shown in Figs. 118 and 119, the latter being a *two-swing extension bracket.*

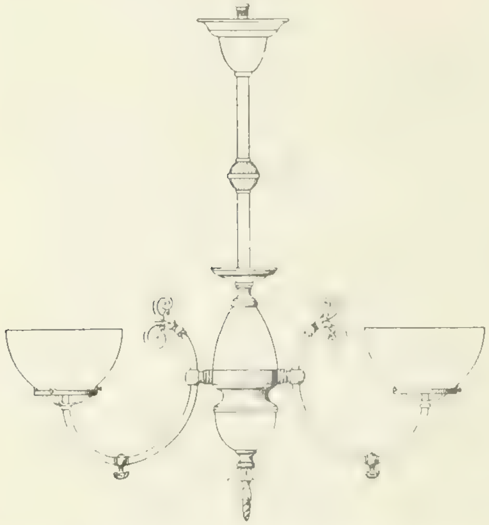


Fig. 121 Ornamental Type of Two Burner Gasolier.

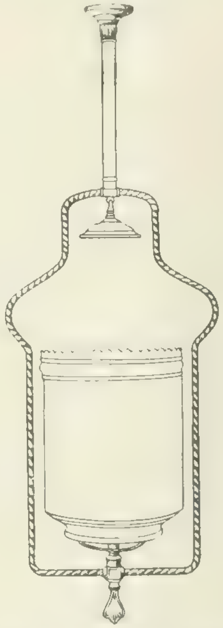


Fig. 122 Gasolier for Hall or Corridor

There are an endless variety of gasoliers used, depending upon the kind of building, the finish of the room, and the number of lights required. Figs. 120, 121, and 122 show common forms for dwelling houses the type shown in Fig. 122 being used for halls and corridors.

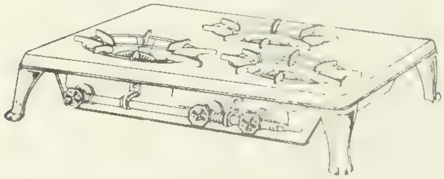


Fig. 123. Simple Form of Gas Plate with Three Burners.

Next to the burner, the shape of the globe or shade surrounding the flame affects the illuminating power of the light. In order to obtain the best results, the flow of air to the flame must be steady and uniform. Where the air supply is insufficient, the flame is likely to smoke; on the other hand, too strong a current of air causes the light to flicker and become dim through cooling.

Globes with openings too small at the bottom, should not be used. Four inches at the bottom should be the smallest opening used for an ordinary size burner. All glass globes absorb more or less light, the loss varying from 10 per cent for clear glass, to 70 per cent or more for opal, ground, colored, or painted globes. Clear glass is therefore much more economical, although, where softness of light is especially desired, the use of opal or ground globes is made necessary.

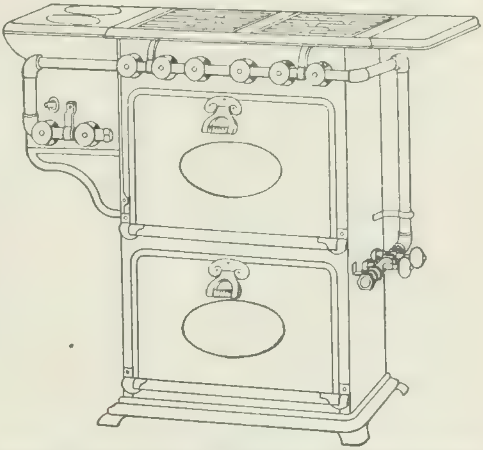


Fig. 124. Gas Range for Family Use, with Ovens and Water-Heater

Cooking as well as heating by gas is now very common, and there are a great variety of appliances for the use of gas in this way. Cooking by gas is not more expensive, and is less troublesome, than by coal, oil, or wood. It is also more healthful, on account of the absence of waste heat, smoke, and dust. A gas range is always ready for use, and is instantly lighted by applying a match to the burner. The fire, when kindled, is at once capable of doing its full work; it is easily regulated, and can be shut off the moment one is through with it, so that, if properly managed, there is no waste as is the case with other fuel. With gas, the kitchen can be kept comparatively cool and comfortable in summer.

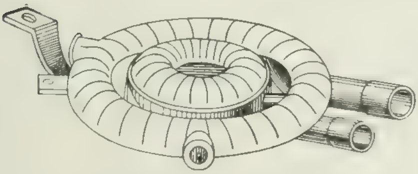


Fig. 125. Griddle Burner for Gas Range.

Fig. 126. Oven Burner for Gas Range.

Gas stoves are made in all sizes, from the simple form shown in Fig. 123, to the most elaborate range for hotel use. A range for family use, with ovens and water-heater, is shown in Fig. 124. Figs. 125 and 126 show the forms of burners used for cooking, the former being a *griddle burner*, and the latter an *oven burner*.

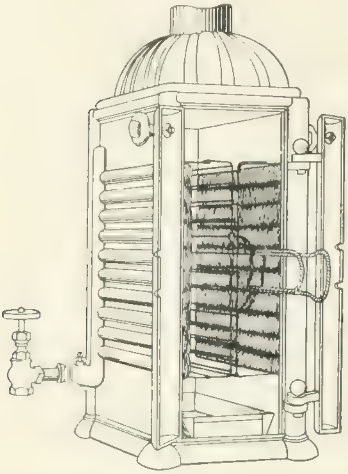


Fig. 127. Gas Broiler, Asbestos-Lined.

A *broiler* is shown in Fig. 127; the sides are lined with asbestos, and the gas is introduced through a large number of small openings. The asbestos becomes heated, and the effect is about the same as a charcoal fire upon both sides.

Gas as a fuel has not been used to any great extent for the warming of whole buildings, its application being usually confined to the heating of single rooms. Unlike cooking by gas, a gas fire for heating is not

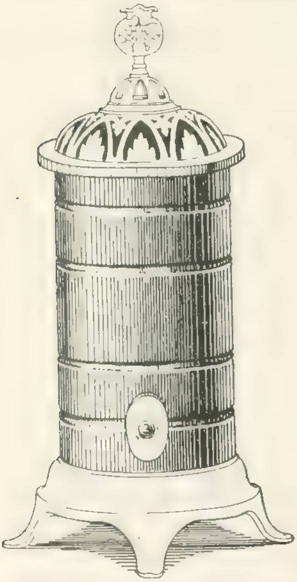


Fig. 128. Common Form of Portable Heater, Connected by Rubber Tubing to Gas-Jet.

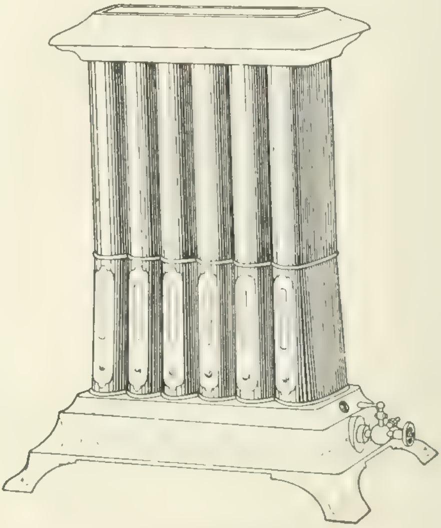


Fig. 129. Gas Radiator.

so cheap as a coal fire when kept burning constantly. In other ways it is effective and convenient. It is especially adapted to the warming of small apartments and single rooms where heat is wanted only occasionally and for brief periods of time. In the case of bedrooms, bathrooms, or dressing-rooms, a gas fire is preferable to other modes of warming, and is fully as economical. It may be used on cold winter days as a supplementary source of heat in houses heated by stoves or by furnaces. Again, a gas fire may be used as a substitute for the regular heating apparatus in a house, in the spring or fall, when the fire in the furnace or boiler has not yet been started. It is often employed as the only means for heating smaller bedrooms, guest rooms, and bathrooms, and for temporary heating in summer hotels where fires are required only on occasional cold days. Any con-

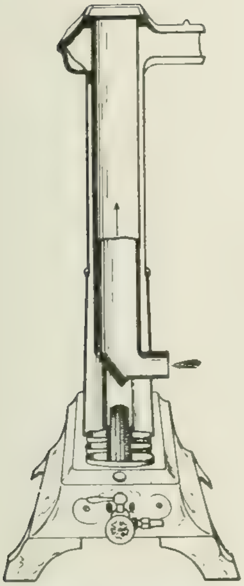


Fig. 130. Section of Gas Radiator of Fig. 129, Showing Flue to Connect to Chimney.

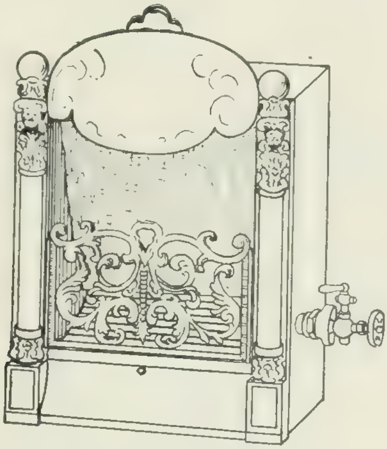


Fig. 131. Asbestos Incandescent Grate,

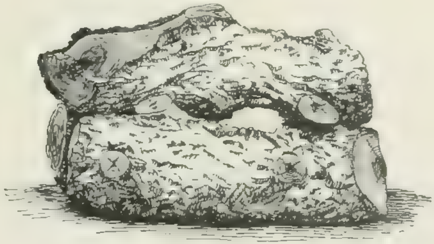


Fig. 132. Gas Log of Metal or Terra-Cotta and Asbestos.

siderable use of gas for heating necessitates the use of evaporators to maintain the normal humidity of the air.

The most common form of heater is that shown in Fig. 128. This is easily carried from room to room, and may be connected with a gas-jet by means of rubber tubing, after removing the tip. The heater is merely a large burner surrounded by a sheet-iron jacket. Another and more powerful gas heater is the *radiator*, shown in Fig. 129. This is fitted with a flue to conduct the products of combustion into the chimney, as shown in the section, Fig. 130. Each section of the radiator consists of an outer and an inner tube, with the gas flame between the two. This space is connected with the flue, while the air to be heated is drawn up through the inner tube, as shown by the arrows.

Fig. 131 shows an *asbestos incandescent grate*; and Fig. 132, a *gas log* of metal or terra-cotta and asbestos, made in imitation of a wood log or heap of logs. The gas issues through small openings in the logs, and gives the appearance of an open wood fire.

Fuel gas or *water gas*, largely made to supplement failing supplies of natural gas, is used for lighting in the same manner as natural gas. It is, in fact, but an impure commercial hydrogen made by injecting steam into hot coke. The oxygen of the steam combines with the carbon of the coke, and sets free the hydrogen, which is collected in a gasometer, ready for the distributing pipes. The prime use of this and of natural gases is for heating; but, by purifying it and supplementing it with carbon by incorporating with it vapors of petroleum, fuel gas makes rich and quite stable lighting gas.

Carburetted air, made by varnishing air with gasoline, generally called *gasoline gas*, is very different from any of the gases mentioned. Carburetted air gas of standard quality contains 15 per cent of gasoline vapor to 85 per cent of air. A regulator or mixer for supplying gas having these proportions is shown, in section, in Fig. 133. In consists of a cast-iron case, in which is suspended a sheet-metal can *B*, filled with air and closely sealed. The balance-beam *E*, to which this is hung, is supported by the pin *H*, on agate bearings. Since the weight of the can *B* is exactly balanced by the ball on the beam *E*, movement of *B* can be caused only by a difference in the weight or density of the gas inside the chamber *A* and surrounding the can *B*. If the gas becomes too dense, *B* rises and opens the valve *C*, thus admitting more air; and if it becomes too light, *C* closes and partially or wholly shuts off the air, as may be required. This gas is not a stable mixture, and great care must be taken, in piping it, to avoid traps and give positive inclination to all the pipe. It is easily condensed by change of temperature; and fixtures through which it is used, must be of a pattern that drain to the keys, so that they can be removed with a screw-driver to drain the arms. The gravity of the mixture varies with the grade of gasoline used. It may always be taken as the weight of air *plus* the gasoline carried with the air. Hence the greatest pressure is always at the lowest instead of the highest point; and instead of lighting a burner by holding the flame over it, we apply the match below. In general, other rules for piping gas apply, with the exceptions mentioned, and these following: the pipe should always be a size larger than for coal gas, except that ¼-inch pipe may be run for two or three burners, and ⅜-inch openings are permissible.

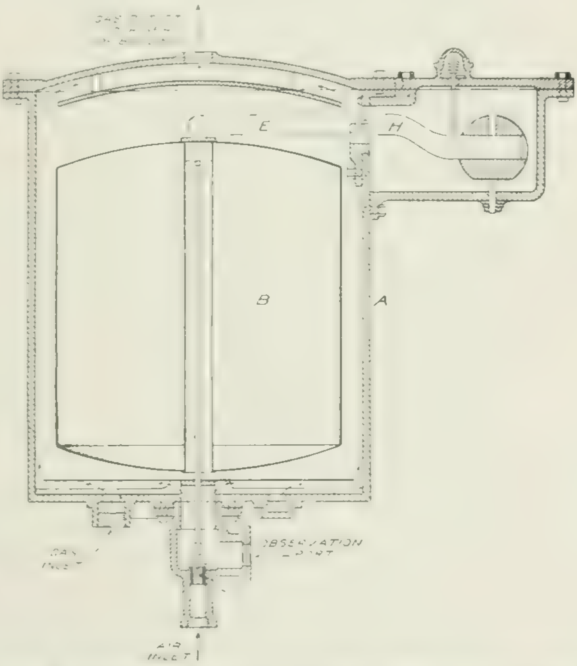


Fig. 133. Regulator or Mixer for supplying Gas and Air Mixed in Certain Proportions.

To avoid having the pressure on the lower floor equal to the friction head of the whole system *plus* the weight of the gas, it is best to pipe the whole supply first to the top of the house. Then feed downward, and drip the main extremities into the initial main with a ¼-inch connection. This permits circulation according to the temperature of the rooms; and, by giving just enough pressure at the pump

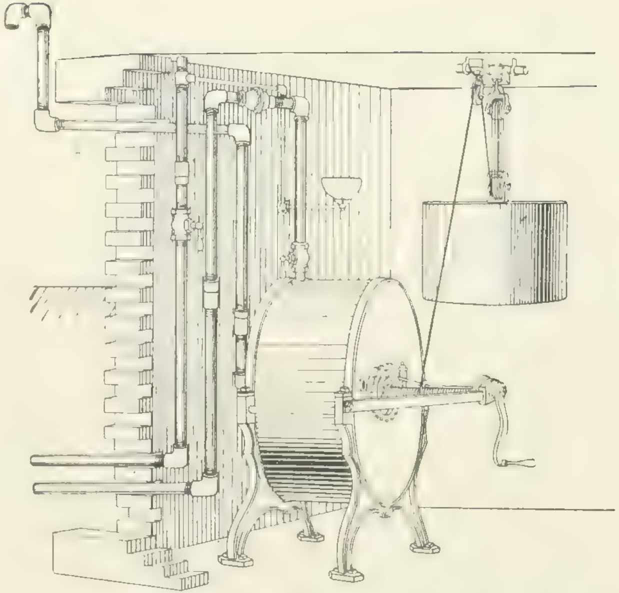


Fig. 134. Pump for Forcing Carburetted Air through House Pipes Operated by Weight and Pulley. Pumps of this Kind are Sometimes Run by City Water-Pressure.

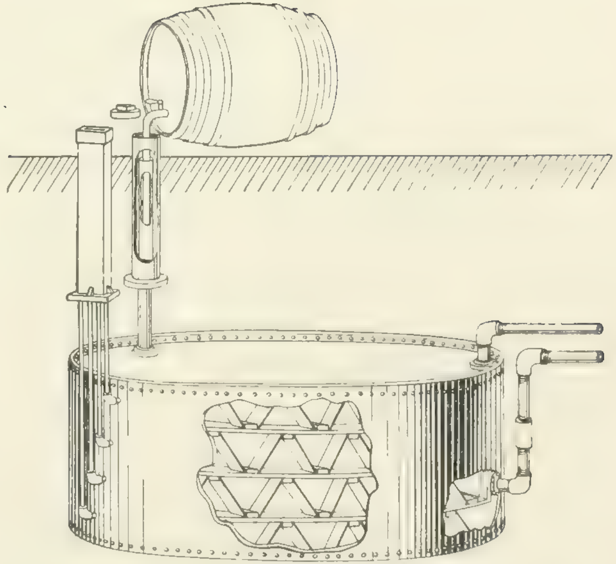


Fig. 135. Carburetter in which Air is Charged with Illuminant by Passing over a Certain Number of Square Inches of Gasoline Surface, Depending on the Number of Burners.

to lift the gas easily to the top of the rising main, it feeds by gravity from that point. The least pressure possible is thus sufficient, and the pressure at each burner is constant.

With the exception of one or two machines, the use of Argand or other special burners is necessary. The *Clough burner*, oftenest used on gasoline, has an annular space below the tip, open at the top only. A thumb-screw passes through the outer case, annular space, and inner wall, to the gas passage. When the carburetter is first filled,

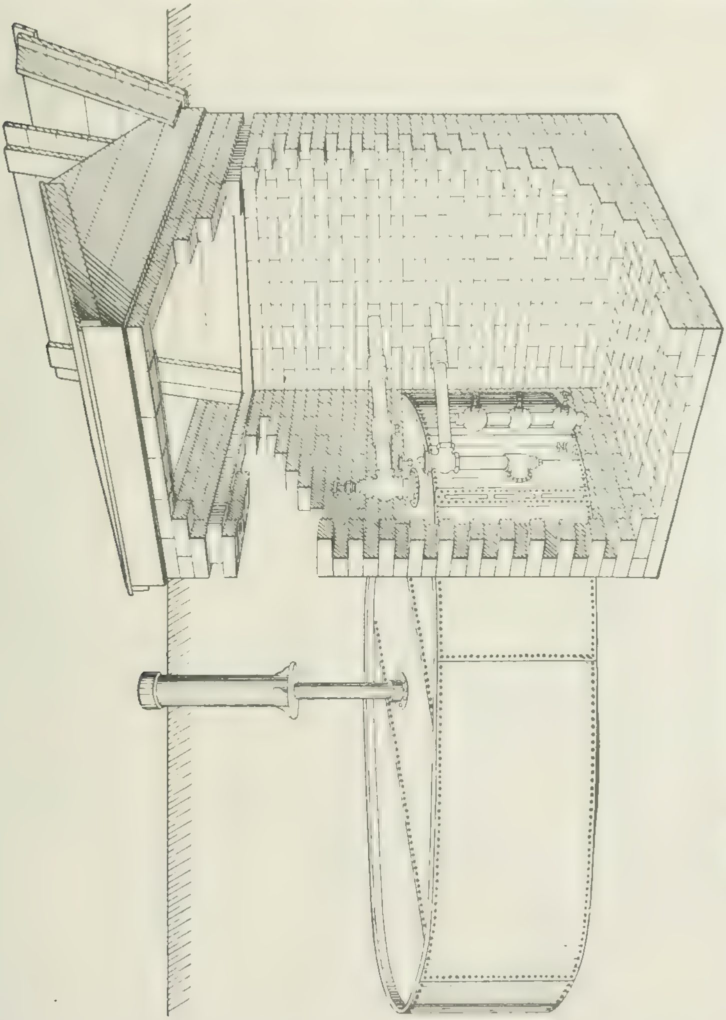


Fig. 136. Carburetter with Pit Giving Access to Transfer Cocks, Pump Pipes, etc.

the gas is too rich, and the thumb-screws of the burners must be screwed out until the gas passing up can suck in more air from the annular space through the screw-hole. The gravity of the gasoline left in the carburetter grows constantly greater; carburization takes place correspondingly slower; and the gas delivered is accordingly poorer. This is because gasoline of various gravities is found in every barrel, and the air takes up the lightest first.

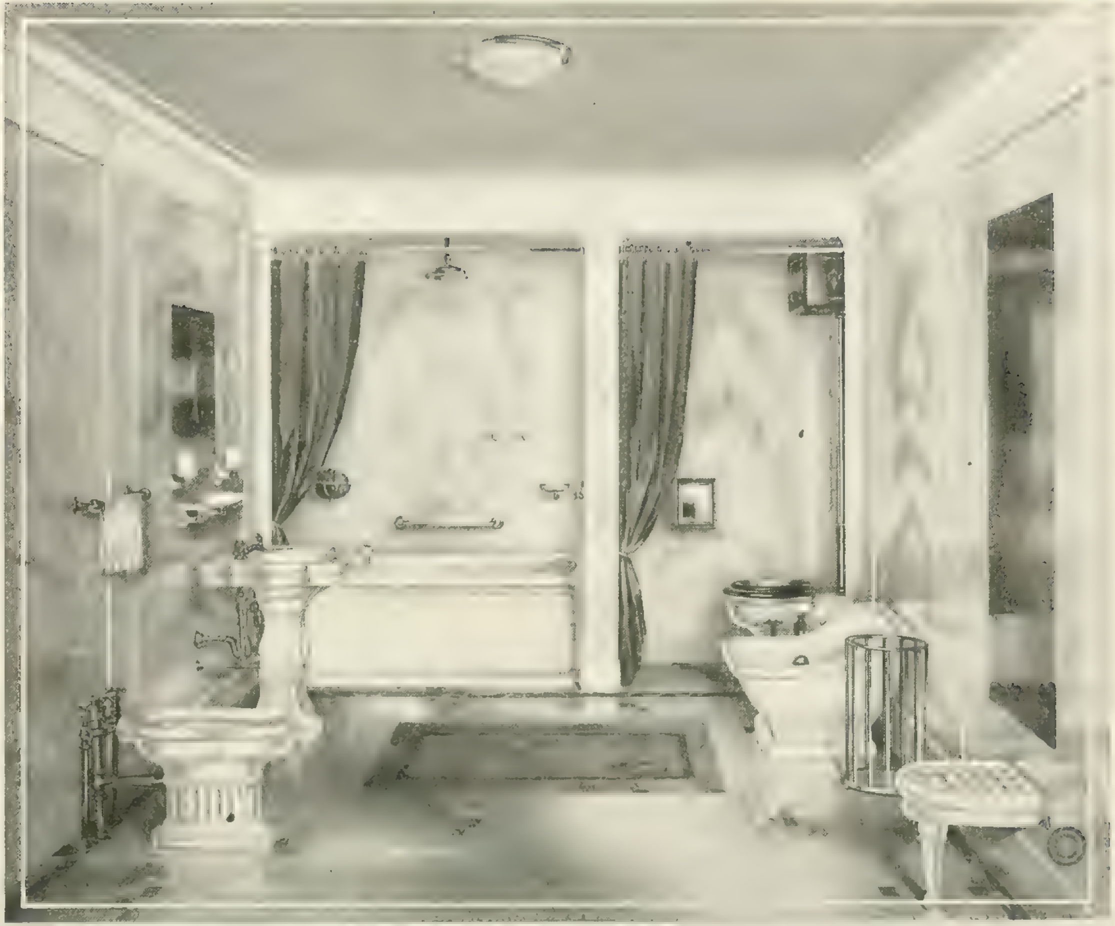
The pump for these machines is a sheet-metal case on legs, with an inner drum, made like the drum of a wet gas-meter and sealed with water. The drum is generally operated by a weight, through the medium of pulleys, and a cord wound on a spool attached to a shaft extending from the drum through a stuffing-box, all about as shown in Fig. 134. The pump is placed in the basement, where it will not freeze. In some makes, city water-pressure is made to run the pump by means of a water-wheel, gravity and impingement of the stream both acting to revolve the drum.

Carburetters are made of sheet metal, galvanized iron, or copper. One form is simply a strong tank with a float and telescope pipe operating through a stuffing-box. The float is hollow, and the air is introduced to the carburetter through it. The weight of the float submerges the holes through which the air enters the carburetter; and, as flotation takes place on the gasoline itself, the air is thus charged with it and ready for the burner. This type of machine will come nearer carburetting all the gasoline of a charge than any other. Its fault is that the gas is too rich and smoky.

Another type of carburetter passes the air over a given number of square inches of gasoline surface per burner, as indicated by the construction shown in Fig. 135. Still another reduces the necessary superficial area of gasoline by looping burlap in the case in such a way as to compel the air to pass through the burlap, which is charged with gasoline by capillary attraction. Charcoal filling has been used for the same purpose.

The shape and dimensions of the simple carburetter have been changed for the better by introducing pans which overflow from one to another when filling. The required superficial surface is obtained in a much smaller case in this way. There is no method, however, of determining the necessary relative capacity of the pans; and transfer cocks, pump pipes, etc., have been resorted to—first, to replenish a pan if it becomes empty, and then to get the heavy residual product into one place where it can be pumped out. This form of machine requires a pit so that one can get down to the cocks and connections. A good form of pit construction is shown in Fig. 136.

Carburetters of nearly every make are placed in the ground, with or without pit, and are required by insurance companies to be at least 30 feet from any building. In some machines, mixers are employed to mix part of the air directly from the pump with the gas after it passes through the carburetter. The proportion of air thus mixed can be varied at will according to the quality of light desired. This feature is intended to make the use of ordinary coal-burners possible. The prices of machines constructed of the same material are a fair gauge of their relative merit.



A MODERN AMERICAN BATH-ROOM, SHOWING INSTALLATION OF FIXTURES
In this Design the Walls are of Marble
James B. Clow & Sons, Chicago

PLUMBING

PART III

METHODS OF SEWAGE DISPOSAL

The fact that no specific gas peculiar to sewers and drains is known, and that the analysis of air taken from the interior of soil pipes has sometimes shown fewer germs capable of producing specific diseases than air taken from the room in which the pipes were situated, affords no reason for abating the effort to exclude drain, sewer, and soil-pipe air from buildings. In cities, the public sewers offer fixed conditions of sewage disposal; but where no public sewer is constructed, there are still a number of ways to handle the sewage from house sewers, and there are but few locations that do not offer at least one chance of settling the question in an unobjectionable manner.

For house disposal, *irrigation*, the *dry-and-wet well plan*, *streams*, and *dry ravines* are among the means most likely to be available. The *septic tank*, too, while its principles have as yet been employed only to a limited extent for individual houses, bids fair to come into extended use in the future.

The first cost of the *garden irrigation plan* is greater, usually, than that of other methods; but it has the merit of fertilizing the soil to some extent as a return for the expenditure. The solid matter must be carted away from time to time. The plan consists essentially of buried lines of irrigating pipe ramifying through the ground to be improved, and a specially formed receiver into which the house pipe leads and from which the irrigating lines are supplied, generally by intermittent siphonage. The solid matter subsides; and when a sufficient body has accumulated, the liquid is siphoned without personal attention. Fig. 137 shows the grease trap and siphon well of a garden irrigation plant. The chambers may be of concrete, or of brick laid in cement mortar and plastered. *KK* are iron cistern-covers with loose tops. The inlet pipe *E* from the house, has a hole in the crown of the bend, to prevent it from becoming air-bound when the well is full. *D* is the overflow to the siphon chamber, through which flows a quantity of sewage corresponding to that which at any time enters through the pipe *E*. *B* is a hood with notched bottom, placed over the central weir *A*. The contents of the siphon well rise through the hood, and pour over into *A* from all points, producing suction, which, with the aid of the tortuous outlet of *A*, causes periodical siphonage of the liquid down to a level below the teeth of the hood. *C* is a cone of wire mesh to protect *B* from becoming accidentally choked. *G* is an air-pipe with strainer at top; *H*, an air and overflow pipe combined; and *I*, the vitrified pipe main to the irrigating lines.

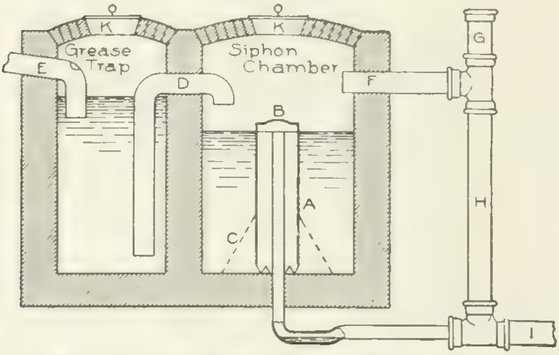


Fig. 137. Grease Trap and Siphon Well of a Garden Irrigation Plant.

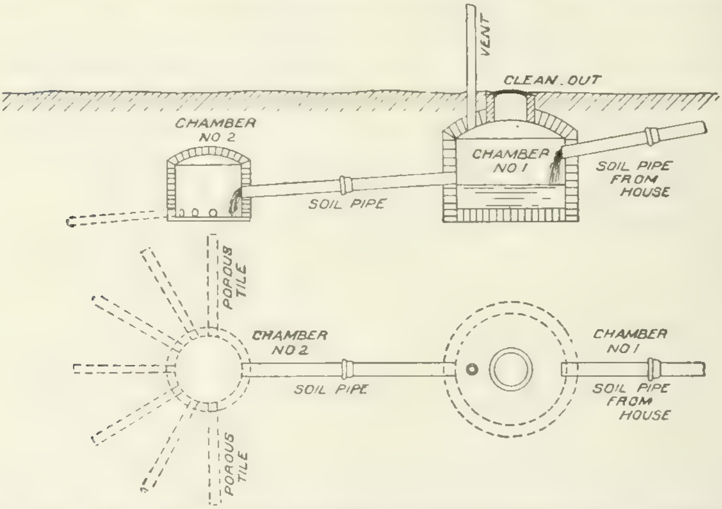


Fig. 138. Sectional Elevation and Plan of Cesspool for Septic Treatment of Sewage.

The irrigating lines are small, hubless, perforated tile arranged to accomplish, by means of tight headers properly inclined, as nearly as possible an even distribution of the liquid. This device—if properly constructed, and if placed at a suitable distance from the house, in such a position that it cannot contaminate a well or other source of water supply—can be used with comparative safety. Special care should be taken in its construction; and when in use, it should be regularly cleaned.

The slope of the ground necessary for the discharge of a siphon, generally meets the requirements of a better process—namely, the *Septic*. A form of cesspool, shown in Fig. 138, is intended for this class of installation. It consists of two brick chambers, the larger having a clean-out opening in the top, provided with a tight cover. A vent pipe is carried from the top to such a height that all gases are discharged at an elevation sufficient to prevent nuisance from their presence. The smaller chamber is connected with the first by means of cast-iron soil-pipe, and is arranged to feed the lengths of porous tile radiating from the bottom, as shown in the plan view. The second chamber thus acts in lieu of the "tight headers" mentioned in connection with Fig. 137. The house drain connects with the larger chamber, which fills to the level of the overflow; then the liquid portion of the sewage drains over into chamber No. 2, and is absorbed through the porous tile branches. The solids, which are small in amount in a properly designed chamber, remain in No. 1, and may require removal from time to time. Unusual dilution and other favoring causes often produce more or less septic action in the second chamber. The intercepting trap may or may not be placed in the house drain.

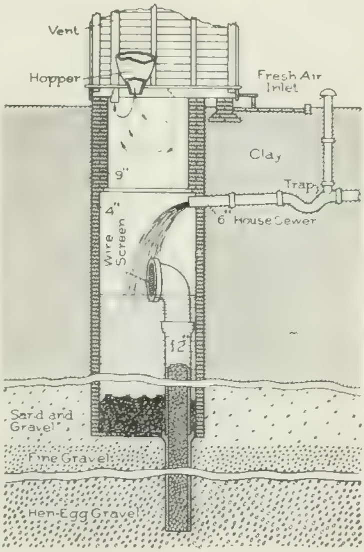


Fig. 139. Sectional Elevation of Dry-and-Wet Well.

Some natural, dry ravines are so formed and located with reference to the general surroundings as to offer little objection to their use as points of discharge for the house drain.

Streams should not be employed, unless they are of considerable size and have a constant flow, so as to accomplish sufficient dilution, unfailing throughout the season.

Near the urban limits, acreage available for disposal areas is small, and the land features and general environment so unfavorable that a *dry well* may sometimes be resorted to. This, in its best form—like the irrigation receiver—separates the solid from the liquid matter, and discharges the overflow of liquid, without much attention, into a stratum of ground in which certain bacterial processes take place. Fig. 139 is an elevation of a dry-and-wet well, which, when properly designed and installed, should operate through a long period without attention.

When the dry-well feature is added to an old vault, it is first necessary to connect the house sewer with the vault. The dry well consists of a 10 or 12-inch tile pipe extending to the gravel stratum and filled with broken rock. This pipe is made water-tight, both where it passes through the bottom of the vault, and within the vault as well. A heavy, grayish scum collects on the surface of the sewage, and indicates septic action. The liquid constantly flows over into the dry well, and some solid matter settles to the bottom.

The mention of this and other types of cesspools is not to be taken as a recommendation for their use, except when compulsory and after careful consideration given to their design. A sparsely settled condition of a locality reduces the harm possible from them; but under the most favorable conditions there is always danger of producing permanent pollution of the soil.

Marshes are sometimes unwisely used as a discharge place for the drain pipe. Isolated low spots covered with loosely piled broken rock to prevent the rooting of plants and to favor bacterial action, have given good service, evaporation and oxidation taking care of the discharge for long periods.

The septic treatment of sewage may be considered a biological rather than a chemical process, as its success is dependent upon presenting conditions which favor the rapid growth of certain bacteria. In the complete reduction of sewage by the septic method, bringing it to a harmless state in the form of nitrates which plant life can assimilate, two forms of bacteria are employed—*anaerobic* and *aerobic.* Air and light retard the multiplication of the first of these The second require oxygen, and multiply rapidly in the open air. The tank or receiver proper, is a sort of catch-basin, made in form to favor the requirements for the propagation of anaerobic bacteria, which reduce the sewage to simple compounds. The tank, it appears, should hold the output of about one day's use of the fixtures discharging into it. Light and air should be excluded. Warmth to a degree is essential. Such heat as is common to a pit in the earth, closed at the top, with no unnecessary exposure, together with the heat of waste water and that generated by the action taking place in the sewage itself, is sufficient to favor the process in winter weather of quite severe climates. A temperature of 54° F. has been stated to be the minimum permissible in this tank, for little or no septic action can take place at lower temperatures. The waste water of baths and lavatories is not turned into the septic tank merely for the heat it brings, but also to secure dilution of the excrement and matter from other sources, which not infrequently carry too little water to favor the best interests of the process. Both the inlet and the outlet of the tank should be arranged to be below the surface of the contents when the tank is full, so that the scum which generally forms on the surface will not be disturbed by entry or exit of matter. This scum, resembling wet ashes, helps to retain the heat, and excludes light and air from the mass—all favoring the accomplishment of the purpose. The scum may be from a few inches to 15 or 20 inches in thickness, according to conditions and nature of the plant.

The contents leaving this initial receptacle, having therein been reduced from a complex nature to one of simpler chemical compounds, principally nitrites, the completion of the reduction process and the change from nitrites to nitrates are brought about by exposure of the matter to light and air, giving the aerobic micro-organisms a chance to develop. This would be accomplished by simply discharging directly into a stream; but a more rapid action is obtained by interposing an open, shallow bed of broken stone or slag for the liquid to flow through first, so as to break up and bring into contact with the air as large an amount of surface as possible before piping to stream or elsewhere. In this way a more complete reduction is certain before the matter reaches any final source of disposal.

The bacteria necessary to the process are always present in abundance in fresh sewage, and nothing more than the time necessary to their cultivation is required in the simplest provision for operation. The resulting product is described as mainly consisting of a harmless, colorless, odorless, stable liquid. In this process, admission of air to the tank, or lack of sufficient heat or dilution, may result in a putrescent state of the matter, such as is occasionally found in a common cesspool.

As already noted, the septic process is not yet widely used, except for town sewage, where it is rapidly gaining in favor. Here elaborate methods are adopted to favor the aerobic or oxidizing end of the operation, mostly through filters of special design, all aiming to secure absolute stability and harmlessness of the final discharge from the sewage disposal plant.

Fig. 140 illustrates a simple arrangement for the septic treatment of sewage. *A* is the septic tank proper, where the anaerobic action takes place; and *B* is the second receptacle, with a bed of broken stone designed to break up the discharge from *A* in a way to favor aerobic action. *C* is the inlet, and *D* the outlet. Wider experience will doubtless develop much data bearing on the form of apparatus and the latitude of conditions under which particular grades of waste can be most successfully treated. Numberless variations from the arrangements shown are being employed, according to size of plant and composition of waste product. From ten to thirty days are required for the development of the bacteria and their action.

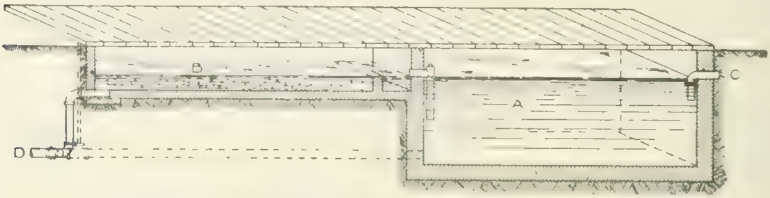


Fig. 140. Simple Tank Arrangement for Septic Treatment of Sewage.

Where the level of the outfall of a sewer for either an individual house or a community is below the level into which the final discharge must be made, it is necessary to use a sewage lift or pump to raise the matter to a point where gravitation will again take care of the flow. These lift pumps may be had suitable for either large or small installations. For sub-cellars or other points below the level of the main drain, surface drainage may be assembled in a well like that shown in Fig. 141; and from there, by means of a cellar drainer operated by steam or water, it may be automatically lifted and discharged into the drain, as shown by the engraving. The well is composed of metal rings about 30 inches in diameter, bolted together. One section is provided with pipe hubs for entry of the surface drain-pipes, and the cap is arranged with manhole opening and cover. If the drain into which the water is discharged is subject to reverse currents from tide or flood water, than a trap, with tide-water valve, arranged as shown between *B* and *C*, is used; otherwise, a simple trapped connection, as indicated by pipe *A*, leads the discharge water into the sewer, and the work shown from *B* to *C* is omitted.

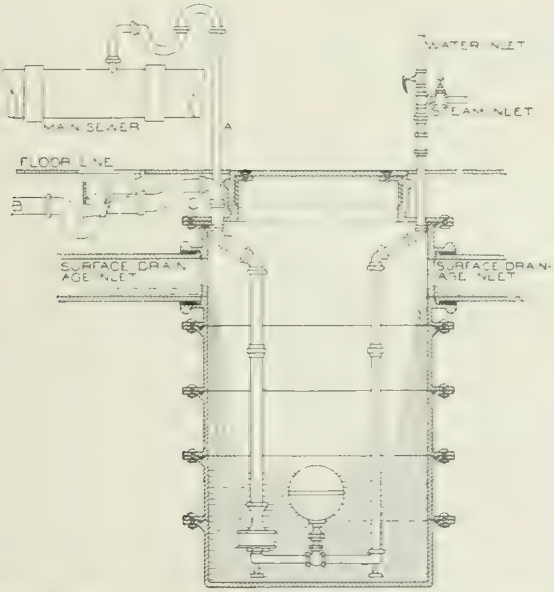


Fig. 141. Well for Collecting Surface Drainage from Sub-Cellars, etc., below Main Drain into which it is Subsequently Lifted and Discharged.

A sanitary sewerage system cannot be installed until a public water supply has been provided. It is needed as soon as that is accomplished; for, while the wells may then be abandoned, the volume of waste water is greatly increased by the more copious water supply. Its foulness is also much increased through the introduction of water-closets. Without sewers and with a public water supply, cesspools must be used; and with these begins a continuous pollution of the soil much more serious than that which commonly results from vaults and the surface disposal of slops.

Among the data which should first be obtained in laying out a sewer system, are:

1. *The area to be served, with its topography and the general character of the soil.* A contour map of the whole town or city, showing the location of the various streets, streams, ponds, or lakes, and contour lines for each 5 feet or so of change in elevation, is necessary for the best results. The general character of the soil can usually be ascertained by observation and inquiry among residents or builders who have dug wells or cellars, or who have observed work of this kind being done. The kind of soil is important as affecting the cost of trenching, as well as its wetness or dryness; and this, together with a determination of the ground-water level, will be useful in showing the extent of under-draining necessary.

2. *Whether the separate or the combined system of sewerage, or a compromise between the two, is to be adopted.* These points will depend almost wholly upon local conditions. The size and cost of combined sewers is much greater than the separate system, since the surface drainage in times of heavy rainfall is many times as great as the flow of sanitary sewage. In older towns and cities, it sometimes happens that drains for removing the surface water are already provided; and in this case it is necessary only to put in the sanitary sewers; or again, the latter may be provided, leaving the matter of surface drainage for future consideration.

If the sewage must be purified, the combined system is out of the question, for the expense of treating the full flow in times of maximum rainfall would be enormous. Sometimes more or less limited areas of a town may require the combined system, while the separate system is best adapted for the remainder; and, again, it may be necessary to take only the roof water into the sewers. As already stated, local conditions and relative cost are the principal factors in deciding between the separate and combined systems.

3. *Whether subsoil drainage shall be provided.* In most cases this also will depend upon local conditions. It is always an advantage to lower the ground-water level in places where it is sufficiently high to make the ground wet at or near the surface during a large part of

the year. In addition to rendering the soil dry around and beneath cellars, the laying of underdrains is of such aid in sewer construction as to warrant their introduction for this purpose alone. This is the case where the trenches are so wet as to render the making and setting of cement joints difficult. The aim in all good sewer work is to reduce the infiltration of ground water into the pipes to the smallest amount; but in very wet soil, tight joints can be made only with difficulty, and never with absolute certainty. Cases have been known where fully one-half the total volume of sewage consisted of ground water which had worked in through the joints.

4. *The best means for the final disposal of the sewage.* Until recently it was the custom to turn sewage into the nearest river or lake where it could be discharged with the least expense. The principal point to be observed in the disposal of sewage is that no public water supply shall be endangered. At the present time, no definite knowledge is at hand regarding the exact length of time that disease germs from the human system will live in water. The Massachusetts Legislature at one time said that no sewer should discharge into a stream within 20 miles of any point where it is used for public water supply; but decisions on this point are now left largely in the hands of the State Board of Health. There may be cases where sewage disposal seems to claim preference to water supply in the use of a stream; but each case must be decided on its own merits. Knowing the amount of water, the prevailing conditions of flow, and the probable quantity and character of the sewage, it is generally easy to determine whether all of the crude sewage of a city can safely be discharged into the body of water in question. Averages in this case should never be used; the water available during a hot and dry summer, when the stream or lake is at its lowest and its banks and bed are exposed to the sun, is what must be considered.

Where sewage is discharged into large bodies of water—either lakes or the ocean—it is generally necessary to make a careful study of the prevailing currents, to determine the most available point of discharge, in order to prevent the sewage becoming stagnant in bays, or the washing ashore of the lighter portions. Such studies are commonly made with floats, which indicate the direction of the existing currents.

5. *Population, water consumption, and volume of sewage for*

which provision should be made, together with the rainfall data if surface drainage is to be installed. The basis for population studies is best taken from the Census reports, extending back many years. By means of these the probable growth can be estimated for a period of from thirty to fifty years. In small and rapidly growing towns, it must be remembered that the rate of increase is generally less as the population becomes greater.

It is desirable to design a sewerage system large enough to serve for a number of years, twenty or thirty perhaps, although some parts of the work, such as pumping or purification works, may be made smaller and increased in size as needed.

The pipe system should be large enough at the start to serve each street and district for a long period, as the advantages to be derived from the use of the city sewers are so great that all houses are almost certain to be connected with them sooner or later. It is often necessary to divide a city into districts, in making estimates of the probable growth in population. Thus the residential sections occupied by the wealthiest classes will consist of a comparatively small population per acre, due to the large size of the lots. The population will grow more dense in the sections occupied by the less wealthy, the well-to-do, and, finally, the tenement sections. In manufacturing districts the amount of sewage will vary somewhat, depending upon the lines of industry carried on.

The total water consumption depends mainly upon the population, but no fixed rule can be laid down for determining it beforehand. It is never safe to allow less than 60 gallons per day *per capita* as the average water consumption of a town, if most of the people patronize the public water supply. In general it is safer to allow 100 gallons.

The total daily flow of sewage is not evenly distributed through the 24 hours. The actual amount varies widely during different hours of the day. In most towns there should be little if any sewage, if the pipes are tight enough to prevent inward leakage, between about 10 o'clock in the evening and 4 o'clock in the morning. From two-thirds to three-fourths of the daily flow usually occurs in from 9 to 12 hours, varying in different communities. This is not of importance in designing the pipe system, but only affects the disposal.

Rainfall data are usually hard to obtain, except in cities and larger towns. In cases of this kind, the data from neighboring towns or cities may be used, if available. Monthly or weekly totals are of little value, as it is necessary to provide for the heaviest rains, as a severe shower of 15 minutes may cause more inconvenience and damage, if the sewers are not sufficiently large, than a steady rain extending over a day or two. A maximum rate of 1 inch per hour will usually cover all ordinary conditions. The proportion which will reach the sewers during a given time will depend upon local conditions, such as the slope of the land; whether its surface is covered with houses and paved streets, cultivated fields, or forests, etc.

6. *Extent and cost of the proposed system.* This is a matter largely dependent upon the local treasury, or the willingness of the people to pay general taxes or a special assessment for the benefits to be derived.

SEWER DESIGN AND CONSTRUCTION

The first step is to lay out the pipe or conduit system. For this, the topographical map already mentioned will be found useful. This, however, should be supplemented by a profile of all the streets in which sewers are to be laid, in order to determine the proper grades. In laying out the pipe lines, special diagrams and tables which have been prepared for this purpose may be used. In the separate system, it is generally best to use 12-inch pipe as the smallest size, to lessen the risk of stoppage, although 8 to 10-inch pipe is ample for the volume of sanitary sewage from an ordinary residence street of medium length. Pipe sewers are generally made of vitrified clay, with a salt-glazed surface. Cement pipe is also used in some cities. The size of pipe sewers is limited to 30 inches in diameter, owing to the difficulty and expense of making the larger pipe, and the comparative ease of laying brick sewers of any size from 24 or 30 inches up. In very wet ground, cast-iron pipe with lead joints is used, to prevent inward leakage or settling of the pipe.

The pipes should be laid to grade with great care, and a good alignment should be secured. Holes should be dug for the bells of the pipe, so that they will have solid bearings their entire length. If rock is encountered in trenching, it will be necessary to provide a bed for the pipe which will not be washed into fissures by the stream of subsoil water which is likely to follow the sewer when the ground is saturated.

Underdrains. Where sewers are in wet sand or gravel, underdrains may be laid beneath or alongside the sewer. These are usually made of ordinary agricultural tiles, 3 inches or upward in diameter. They have no joints, being simply hollow cylinders, and are laid with their ends a fraction of an inch apart, wrapped with cheap muslin cloth to keep out the dirt until the matter in the trench becomes thoroughly packed about them. These drains may empty into the nearest stream, provided it is not used for a public water supply.

Manholes. These should be placed at all changes of grade, and at all junctions between streets. They are built of brick, and afford access to the sewer for inspection; in addition to this, they are sometimes used for flushing. They are provided with iron covers, which in many cases are pierced with holes for ventilation.

Sewer Grades. The grades of sewers should, where possible, be sufficient to give them a self-cleaning velocity. Practical experiments show that sewers of the usual sections will remain clear with the following minimum grades: Separate house connections, 2 per cent (2-foot fall in each 100 feet of length); small street sewers, 1 per cent; main sewers, 0.7 per cent. These grades may be reduced slightly for sewers carrying only rain or quite pure water.

The following formula may be used for computing the minimum grade for a sewer of clear diameter equal to d inches, and either circular or oval in section:

$$\text{Minimum grade, per cent} = \frac{100}{5d + 50}$$

Flushing Devices. Where very low grades are unavoidable, and at the head of branch sewers, where the volume of flow is small, flushing may be used with advantage. In some cases water is turned into the sewer through a manhole, from some pond or stream or from the public waterworks system. Generally, however, the water is allowed to accumulate before being discharged, by closing up the lower side of the manhole until the water partially fills it, and then suddenly releasing it and allowing the water to rush through the pipe. Instead of using clear water from outside for this purpose, it may be sufficient at some points on the system simply to back up the sewage, by closing the manhole outlet, thus flushing the sewer with the sewage itself.

Where frequent and regular flushing is required, automatic devices are often used. These usually operate by means of a self-discharging siphon, although there are other devices operated by means of the weight of a tank which fills and empties at regular intervals.

House Connections. Provision for house connections should be made when the sewers are laid, in order to avoid breaking up the streets after the sewers are in use. Y-branches should be put in at frequent intervals, say from 25 feet upwards, according to the character of the street. When the sewer main is deep down, quarter-bends are sometimes provided; and the house-connection pipe is carried vertically upwards to within a few feet of the surface, to avoid deep digging when connections are made.

Where house connections are made with the main, or where two sewers join, the direction of the flow should be kept as nearly the same as possible, and the entering sewer should be at a little higher level, in order to increase the velocity of the inflowing sewage.

Depth of Sewers below Surface. No general rule can be followed in this matter, except to place the sewers low enough to secure a proper grade for the house connections which are to be made with them. They must be kept below a point where there would be trouble from freezing; but the natural depth is sufficient to prevent this in most cases.

Ventilation of Sewers. There is more or less difference of opinion in regard to the proper method of ventilating sewer mains. Ventilation through soil-pipe foul-air outlets carried above the roof-level, with the aid of street manhole gratings, constitutes the usual procedure, though not entirely satisfactory. If air inlets and outlets were placed on the main sewers at intervals of 300 feet or so, the accumulation of air-pressures which now obtains would be prevented. The omission of all intercepting traps would result in the uniform ventilation of the public sewers through the various house pipes, and, in the opinion of many students of the subject, is highly desirable.

The Combined System. The principal differences between the combined and the separate system lie in the greater size of conduits in the combined system, and the admission of surface water. Combined sewers are generally of brick, stone, or concrete, or a combination of these materials, instead of vitrified pipe. Another difference is the provision for *storm overflows*, by means of which the main sewers, when overcharged in times of heavy rainfall, can empty a part of their contents into a nearby stream. At such times the sewage is diluted by the rain-water, while the stream which receives the overflow is also swollen.

Size, Shape, and Material. The actual size of the sewer, and also to a large extent its shape and the material of which it is constructed, depend upon local conditions. Where the depth of flow varies greatly, it is desirable to give the sewer a cross-section to suit all flows as fully as possible.

The best form of section to meet these requirements is that of an egg with its smaller end placed downward. With this form the greatest depth and velocity of flow are secured for the smallest amount of sewage, thus reducing the tendency to deposits and stoppages. Where sewers have a flow more nearly constant and equal to their full capacity, the form may be changed more nearly to that of an ellipse.

For the larger sewers, brick is the most common material, both because of its low cost and the ease with which any form of conduit is constructed. Stone is sometimes used on steep grades, especially where there is much sand in suspension, which would tend to wear away brick walls. Concrete is used where leakage may be expected or where the material is liable to movement, but is more commonly used as a foundation for brick construction.

A *catch-basin* is generally placed at each street corner, and provided with a grated opening for giving the surface water access to a chamber or basin beneath the sidewalk, from which a pipe leads to the sewer. Catch-basins may be provided with water traps to prevent the sewer air from reaching the street; but traps are uncertain in their action, as they are likely to become unsealed through evaporation in dry weather. To prevent the carrying of sand and dirt into the sewers, catch-basins should be provided with silt chambers of considerable depth, with overflow pipes leading to the sewer. The heavy matter which falls to the bottom of these chambers may be removed by buckets and carted away at proper intervals.

Storm Overflows. The main point to be considered in the construction of storm overflows is to ensure a discharge into another conduit when the water reaches a certain elevation in the main sewer. This may be carried out in different ways, depending upon the available points for overflow.

Pumping Stations. The greater part of the sewerage systems in the United States operate wholly by gravity; but in some cases it is necessary to pump a part or the whole of the sewage of a city to a higher level. In general the sewage should be screened before it reaches the pumps.

Where pumping is necessary, receiving or storage chambers are sometimes used to equalize the work required of the pumps, thus making it possible to shut down the plant at night. Such reservoirs should be covered, unless in very isolated localities. The force main or discharge pipe from the pumps is usually short, and is generally of cast iron put together in a manner similar to that used for water-supply systems.

Tidal Chambers. Where sewage is discharged into tide water, it is often necessary to provide storage or tidal chambers, so that the sewage may be discharged only at ebb tides. These are constructed similar to other reservoirs, except that they must have ample discharge gates, so that they can be emptied in a short time. They are sometimes made to work automatically by the action of the tide.

SEWAGE PURIFICATION

Before taking up this subject in detail, it will be well to consider what sewage is, from a chemical standpoint.

When fresh, sewage appears at the mouth of an outlet sewer as a milky-looking liquid with some large particles of matter in suspension, such as orange peels, rags, paper, and various other articles not easily broken up. It often has a faint, musty odor, and in general appearance is similar to the suds-water from a family laundry. Nearly all of the sewage is water, the total amount of solid matter not being more than 2 parts in 1,000, of which half may be organic matter. It is this 1 part in 1,000 which should be removed, or so changed in character as to render it harmless.

The systems of purification now in most common use are the *septic treatment* already described, *chemical precipitation*, and the *land treatment*. *Mechanical straining*, *sedimentation*, and *chemical precipitation* are largely removal processes; while *land treatment*, by the slow process of infiltration or irrigation, changes the decaying organic matter into stable mineral compounds.

Sedimentation. This is effected by allowing the suspended matter to settle in tanks. The partially clarified liquid is then drawn off, leaving the solid matter, called *sludge*, at the bottom for later disposal. This system requires a good deal of time and large settling-tanks, and until recently has been considered suitable only for small quantities of sewage.

Mechanical Straining. This is accomplished in different ways, with varying degrees of success. Wire screens or filters of various materials may be employed. Straining of itself is of little value except as a step to further purification. Beds of coke from six to eight inches in depth are often used with good results.

Chemical Precipitation. Sedimentation alone removes only such suspended matter as will sink by its own weight during the comparatively short time which can be allowed for the process. By adding certain substances, chemical action is set up, which greatly increases the rapidity with which precipitation takes place. Some of the organic substances are brought together by the formation of new compounds; and, as they fall in flaky masses, they carry with them other suspended matter.

A great number and variety of chemicals have been employed for this purpose; but those which experience has shown to be most useful are lime, sulphate of alumina, and some of the salts of iron. The best chemical to use in any given case depends upon the character of the sewage, and on relative cost in the particular locality where it is to be used. Lime is cheap, but the large quantity required greatly increases the amount of sludge. Sulphate of alumina is more expensive, but it is often used to advantage in connection with lime. Where an acid sewage is to be treated, lime alone should be used.

The chemicals should be added to the sewage, and thoroughly mixed, before it reaches the settling-tank; this may be effected by the use of projections or baffling-plates placed in the conduits leading to the tank. The best results are obtained by means of long, narrow tanks; and they should be operated on the *continuous* rather than the *intermittent* plan. The width of the tank should be about one-fourth its length. In the continuous method, the sewage is constantly flowing into one part of the tank and discharging from another. In the intermittent system, a tank is filled and then the flow is turned into another, allowing the sewage in the first tank to come to rest. In the continuous plan, the sewage generally flows through a set of tanks without interruption until one of the compartments needs cleaning. The clear portion is drawn off from the top, the sludge is then removed, and the tank thoroughly disinfected before being put in use again.

The satisfactory disposal of the sludge is a somewhat difficult problem. The most common method is to press it into cakes, which greatly reduces its bulk and makes it more easily handled. These are sometimes burned, but are more often used for fertilizing purposes. In some cases, peat or some other absorbent is mixed with the sludge, and the whole mass removed in bulk. In other instances, the sludge is run out on the surface of coarse gravel beds, and reduced by draining and drying. In wet weather, little drying takes place; and during the cold months, the sludge accumulates in considerable quantities. This process also requires much manual labor, and in many cases suitable land is not available for the purpose. The required capacity of the settling-tanks is the principal item in determining the cost of installing precipitation works.

In the treatment of house sewage, provision must be made for about $\frac{1}{12}$ the total daily flow; and in addition to this, allowance must be made for throwing out a portion of the tanks for cleaning and repairs. In general, the tank capacity should not be much less than $\frac{1}{8}$ the total daily flow.

In the combined system, it is impossible to provide tanks for the total amount; and the excess due to storm water must discharge into natural watercourses or pass by the works without treatment.

Broad Irrigation or Sewage Farming. Where sewage is applied to the surface of the ground upon which crops are raised, the process is called *sewage farming*. This varies but little from ordinary irrigation, where clean water is used instead of sewage. The land employed for this purpose should have a rather light and porous soil, and the crops should be such as require a large amount of moisture. The application of from 5,000 to 10,000 gallons of sewage per day per acre is considered a liberal allowance. On the basis of 100 gallons of sewage per head of population, this would mean that one acre would care for a population of from 50 to 100 people.

Sub-Surface Irrigation. This system is employed, as already described, only upon a small scale, and chiefly for private dwellings, public institutions, and small communities where for any reason surface disposal would be objectionable. The sewage is distributed through agricultural drain tiles laid with open joints and placed only a few inches below the surface. Provision should be made for changing the disposal area as often as the soil may require, by turning the sewage into other subdivisions of the distributing pipes.

Intermittent Filtration. This method, and the broad irrigation already described, are the principal purification processes—not considering the septic method—in use on a large scale, which can remove practically all the organic matter from sewage without being supplemented by some other method. The process is a simple one, and consists in running the sewage out through distributing pipes on beds of sand 4 or 5 feet in thickness, with a system of pipes or drains below for collecting the purified liquid. In operation, the sewage is turned first on one bed and then on another, thus allowing an opportunity for the liquid portion to filter through. As the surface becomes clogged, it is raked over, or the sludge may be scraped off together with a thin layer of sand. The best filtering material consists of a clean, sharp sand with grains of uniform size, such that the free space between them will equal about one-third the total volume. When the sewage is admitted to the sand, only a part of the air is driven out, so that there is a store of oxygen left, upon which the bacteria may draw. This is not a mere process of straining, but the formation of new compounds by the action of the oxygen in the air, thus changing the organic matter into inorganic. Much depends upon the size and quality of the sand used.

The work done by a filter is largely determined by the finer particles of sand, and that used should be of fairly uniform quality, and the coarser and finer particles should be well sized. The area and volume of sand or gravel required are so large that the transportation of material any great distance is out of the question. Usually the beds are constructed on natural deposits, the top soil or loam being removed. The sewage should be brought into the beds so as to disturb their surface as little as possible, and should be distributed evenly over the whole bed.

The underdrains should not be placed more than 50 feet apart, usually much less, and should be provided with manholes at the junctions of the pipes. Before admitting the sewage to the beds, it is usually best to screen it sufficiently to take out paper, rags, and other floating matter. The size and slope of each bed should be such as to permit an even distribution of sewage over its surface.

Where the filtration area is small, it must be divided so as to permit of intermittent operation; that is, if a bed is to be in use and at rest for equal periods, then two or more beds will be necessary, the number depending on the relative periods of use and rest. Some additional area should also be provided for emergency, or for use while the beds are being scraped. If a large area is laid out, so that the size of the beds is limited only by convenience in use, then an acre may be taken as a good size.

The degree of purification depends upon various circumstances; but with the best material, practically all of the organic matter can be removed from sewage by intermittent filtration, at a rate of about 100,000 gallons per day.

There is often much opposition to sewage purification by those living or owning property near the plants; but experience has shown that well-conducted plants are inoffensive, both within and without their enclosures. The employees about such works are as healthy as similar classes of men in other occupations. The crops raised on sewage farms are as healthful as those of the same kind raised elsewhere; and meat and milk from sewage farms are usually as good as when produced under other conditions. Good design and construction, followed by proper methods of operation, are all that are needed to make sewage purification a success. No one system can be said to be the best for all localities. The special problems of each case must be met and solved by a selection from among the several systems and combinations of systems, and parts chosen that are best adapted to the conditions at hand.

Where sewerage and storm water are carried in one system of pipes or conduits, rain-water leaders may ventilate the drain more or less. Trapping a leader drain is often unnecessary, if it opens above the highest windows. Porch and veranda roof drains having windows above them may require trapping, but it should be done in a way to insure the maintenance of the water-seal of the trap. As these drains are small, merely connecting to the main drain inside (on the house side), the main intercepting trap may be deemed sufficient unless closure by hoar frost is likely. Other pipes so connected being higher, the chances are that air will enter the open end to supply a current up the taller lines; and if this is not the case, dilution of what air may be thus brought into the open will render its danger of little consequence. Care must be taken in the design of a system of plumbing, that leader traps are not omitted where such omission would result in the weakening of the flow of air through the principal vent pipes.

THE HOUSE DRAINAGE SYSTEM

Assuming that the method of disposing of sewage and drainage is decided upon, the problem of how to pipe the house safely may be considered as presenting about the same conditions, whether the house drain enters a branch from the city sewer or terminates in some other means of disposal.

Granted that sewer air is a thing to be guarded against, the safest plan is to pursue that course which offers the surest means of keeping the house free of it. We know that through contamination of water supply by filtration from vaults, etc., the human system may suffer pollution, and may develop specific disease of a serious, even fatal nature. It is no less certain that polluted air will affect the lungs similarly, according to the nature of the pollution. On this ground, notwithstanding any argument to the contrary, we should proceed to exclude sewer air entirely, and to make the air of the house drain-pipes as pure as possible.

It must be remembered that where a whole system of plumbing is designed with certain ends in view, and all the details worked out accordingly, a house system may be satisfactory which under slight disturbance of conditions would be abominable. Therefore no departure from a certain means of positively accomplishing a desired result should be accepted without unanimous endorsement of those in position to know what is safe. People, however, have been at all times too ready to accept any plan that promised the immediate saving of a dollar. Certain plumbing accessories may be admirably adapted to use in one place, yet wholly unfit for service in another; but the makers cannot be expected to discriminate; they are prejudiced, and are not on the ground. It is the business of the public, through architects and plumbers, to select suitable means to the end.

With the fresh-air inlet and proper installation throughout the building, an intercepting trap is likely to exclude sewer air from the house, and to keep the drains in the house filled with fresh air from the open atmosphere (see page 163). With these conditions, a possible leaky joint or defective trap can permit only comparatively pure air to enter from the pipe. The intercepting trap being in the main line, all water from the house passes through it, insuring the water seal being maintained. The foul-air outlet ventilates the sewer much as would the house lines if the trap were omitted, because in it there is never any contrary rush of air or water, both of which would check or reverse the current, and the latter of which reduces the area of the pipe, even though it be assumed that no further interference occurs through discharge from fixtures. The trap may be in the yard or within the house walls, according to circumstances.

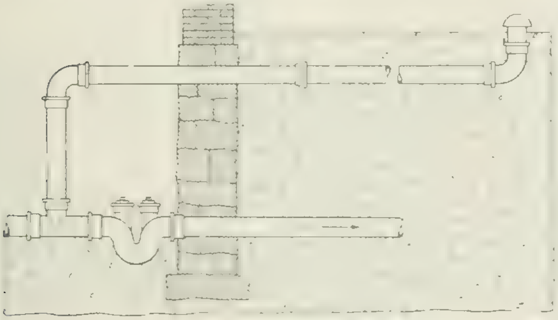


Fig. 142. Intercepting Trap in Cellar.

Fig. 142 shows an intercepting trap in the cellar, with its fresh-air inlet terminating above the snow-level. Many jobs were formerly piped in a way permitting soil air to puff out through the inlet. Fig. 143 shows a plan that has been resorted to with the idea of carrying such discharges to a safe height without interfering with the normal action of the fresh-air inlet. It is merely a rising line with an inverted funnel over the open end of the inlet, which incidentally protects the air-pipe from lodgment of foreign matter. The foul-air outlet should not terminate near a window or

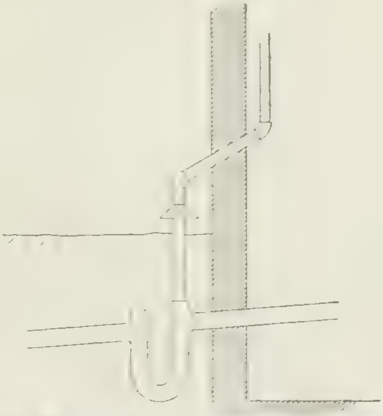


Fig. 143. Simple Device for Carrying Away to a Safe Height Soil Air that may be Puffed from Fresh-Air Inlet.

door, nor be too close to the fresh-air inlet opening. It should be located so that it will be free of chance obstruction, and above the level of winter ice and snow, even though it has to be piped to above the roof-level as indicated in Fig. 144, in which *A* is a cone strainer with solid top, and *T* the main intercepting trap. The direct line of foul-air pipe to roof, and the distance between the trap and fresh-air inlet grating, provide every requisite possible to this part of the house drainage, whether a *loop stack*, spoken of on another page, is employed or not.

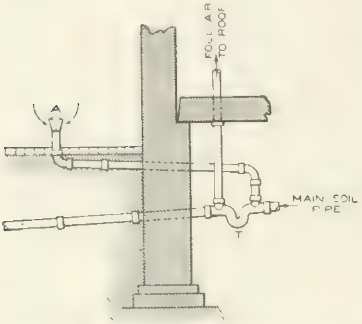


Fig. 144. Foul-Air Outlet from Intercepting Trap Carried to Roof.

A very good plan of terminating air inlet and outlet pipes in situations exposed to the entrance of obstacles, is to use a single or double hub return bend above snow-level, as shown in Fig. 145. In this way, nothing can fall in by accident; sleet from any direction cannot choke the openings; nor are children likely to fill the pipe.

Fig. 146 illustrates a galvanized-wire guard placed in the hub; such a guard is generally used on conductor pipe, but is equally suited to the protection of soil and vent lines in mild climates. In Northern localities, the regular cast hood and thimble made for the purpose are better. The area of the openings of the strainer should aggregate at least 12 square inches for pipe 4-inch or less; and where frost trouble is feared, the strainer should be recessed several inches so that the frost will have to close the open end of the pipe instead of the grating.

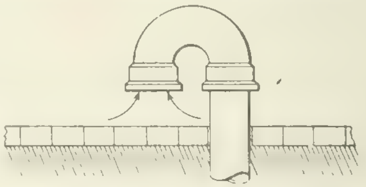


Fig. 145. Return Bend Used to Terminate Air Inlet or Outlet Pipe.

The foul-air pipe should not have abrupt offsets at any point. The lodgment of foreign matter therein would be possible, and the function of the pipe perhaps thus impaired. This pipe not only ventilates the sewer, but offers egress for air when storm water is crowding the sewer, and at other times when air-pressure would otherwise drive the seal of the trap toward the house, enough ultimately, in some cases, to lose the seal by waving out when the pressure is relieved.

When a trap loses its seal by waving out, the water, in flowing back to its normal position, gains momentum enough to throw some of it over the weir, and the balance is not enough to seal the trap. Waving out is always caused, first, by air-pressure on the sewer side, and then by gravity acting as described.

The operation of the fresh-air inlet depends on air from the open entering the house drain near the trap and filling the house system, passing out through the vent pipe above the roof. The inlet should be as large as the house sewer, which should never be less than 4 inches diameter, usually 5 inches. The same precautions taken against snow and ice and other obstructions to the foul-air outlet, are necessary to the fresh-air inlet. The difference in level of the inlet and the exit, together with the warmth of the building, causes an upward current through the stack. Even the taking a more exposed course and stopping at an elevation inferior to the outlet of the soil-pipe extension, when necessary to carry the inlet to the roof, will usually insure a draft.

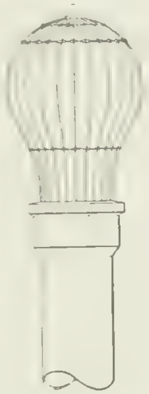


Fig. 146.
Galvanized-Wire
Guarded End
of Pipe.

Objection is often raised against the fresh-air inlet, for the reason that puffs of foul air are thrown out when fixtures are discharged. This is easily possible, but mainly the result of faulty installation. One feature of plumbing is no more likely to be satisfactory than another where ignorance prevails, or when merely the simple letter instead of the spirit of ordinary specifications is lived up to. House main lines of the same size as soil-stacks (4-inch) will cause puffs of air from the fresh-air inlet if the horizontal run and the inlet branch are both short. It is well to remember that the air so puffed out is not sewer air. It is air which has just entered the house system from the open. And, if the fresh-air branch is of decent length, as described, and as shown in Fig. 144, the puff occasioned by the discharge of a fixture in an ordinary house, even in an objectionable job, may not equal a third of the really fresh air in the inlet branch.

The chance of puffing under the action of fixtures can be avoided by a loop providing for simple revolution of air when fixtures are discharged. A soil-stack from the main horizontal line is carried up to the roof, with all connections as usual, except one. This is made above the highest fixture, and of the same size as the soil-stack, and is generally carried down and connected, as it should be, into the horizontal main several feet nearer the intercepting trap than where the corresponding soil-stack leaves the main. Some connections are so close to the point of exit that the vertical stacks are made to constitute the whole loop, as shown in Fig. 147, in which cases the direct stack *E* from *X* to *Y* should invariably be a portion of the vent. If the connection *X* is made in the horizontal run, as before mentioned, stack *F* should be the vent, as a rule, instead of carrying the closet branches *GG* as shown. *V* and *V* are crown vents for the closets. The crown vents may in some situations be made into a separate smaller line leading into the soil-stack above the highest fixture.

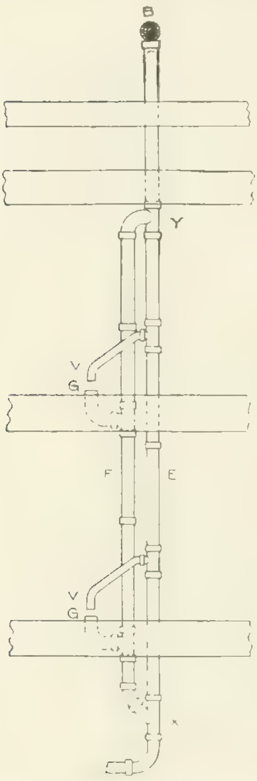


Fig. 147. Loops in Soil Stack to Prevent Puffs of Air at Fresh Air Inlet.

By the *loop* plan, air is thrust before the water discharged from a fixture as usual; also, there is the same tendency to a vacuum behind the water so discharged. But, instead of reversing the general current and drawing air from the roof to fill the void, the roof current in the soil-stack from the loop connection up, is merely checked, more or less; and the air already rising in the loop turns down the soil-stack and fills the void. Without the loop, considerable compression would take place in front of the water before the current in the house main could be reversed. With the loop, this compression is confined principally to the stack. The void being supplied by the loop, the air driven in front of the water simply passes up the loop in response to the call for air to fill the void behind the water.

Referring again to Fig. 147, air takes the course offering the least friction; and *F* branching out of and into *E*, which is the same size pipe as shown at *X* and *Y*, the greater part of a current of air passing upward through them will travel by pipe *E*. For this and other reasons it is best to take the branch pipe *F* for the soil pipe. Then, whatever offset may be necessary to reach the closet openings will be washed; and the straight, vertical stack left for the vent affords no chance for the lodgment of rust or other obstruction. When water is discharged into the soil pipe at *G*, pipe *Y* protects the closet trap from siphonage; and the tendency to form a vacuum above the water in the soil pipe by the piston action of the discharge water, is neutralized by a proportional draught of air from vent pipe *E* through branch *Y*. The air in the vent pipe between *Y* and *B* tends to continue its course to the roof, while that below the branch *Y* is traveling toward branch Y. A partial vacuum formed in soil pipe *F* by a discharge from a fixture, will be checked by a supply of air drawn from vent pipe *E* between branches *X* and *Y*. The vacuum formed behind the discharge water in soil pipe *F* increases the upward velocity of air in vent pipe *E* below *Y*; and the air pushed down in front of the discharge attempts to reverse the current below *X*. The increased velocity of the air in pipe *E* demands more air than was passing through it by natural draught. This demand is supplied by the extra volume which the water is pushing before it.

As long as the discharge water is above branch *X*, the air simply revolves in the two pipes which form the loop. The air in pipe *F* travels downward before the water, and up through pipe *E* and branch *Y*, and down pipe *F* behind the water. This revolution of air in the loop continues until the water reaches the junction *X* of pipes *E* and *F*, without causing any perceptible "puff" at the fresh-air inlet opening.

When both the connections are in vertical lines as in Fig. 147, after the water passes *X*, it will probably reverse the current of air in the fresh-air pipe in some instances; but, were it possible to shove out every atom of air in the soil pipe between the trap and point *X*, there still would not be a particle of foul air puffed out at the fresh-air opening, if the fresh-air pipe is of greater length than the distance between *X* and the trap.

After the fixture water reaches *X* connection when *X* is made in a larger and horizontal pipe, its interference with the air is not considerable.

The object in not connecting the loop stacks as close together as fittings will permit, is to keep the water, as it turns into the horizontal main, from interfering with the entry of air to the vent. By giving some distance to travel before reaching the loop connection, the discharge of water will be well spread in the main line before passing it. From this point on, it may cause violent eddying of the air in the main, but no actual reversal of the current will take place.

The force of air in front of water in down spouts that connect inside of the intercepting trap, may at times reverse the air in the fresh-air inlet proper. The loop pipe is an aid in this respect, too, as more air is at hand to cushion the rush of a sudden downpour; and the various fixture trap seals are, if affected at all, left much more stable. It would, if necessary, be better to have soil-pipe air expelled from an inlet, at times, by the action of storm water, than to incur the risk of siphonage or waving-out of fixture trap seals for lack of it.

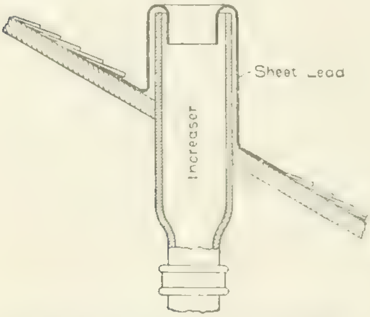


Fig. 148. Vent Pipe Increased in Size Before Passing Through Roof to Prevent Closure by Hoar Frost.

No pipe of any building should open to the air with less than a 4-inch end. Small pipes should be increased to 4 inches before passing through the roof, as shown in Fig. 148. Pipe 4-inch and larger, up to 6-inch, should be increased to 6-inch. The object in all cases being to prevent closure by hoar frost. With 6-inch and larger pipe, it is doubtful if it is ever necessary to increase the size at the roof, excepting in buildings with cold roof space, no matter how high the building may be; yet some city ordinances call for an increase of one size regardless of size, which is manifestly foolish, as it permits increasing 2-inch to 2½ or 3-inch on any type of job, and this is known to be inadequate in any but southerly latitudes. The velocity of air up the line is, of course, higher in tall buildings than in low ones; hence, in them, more moisture is carried through any given opening, and the theory of increasing large pipe at the exit is based on the assumption that smaller openings would, as a result of this excess of moisture, be closed by frost. The great amount of warmth over large buildings must often, however, be considered as reducing the chances of closure by hoar frost. In tropical climates, no increase of any size is necessary. In southerly temperate latitudes, no special attention is given precautions against hoar frost, beyond increasing the size of small vents to at least 4 inches in diameter.

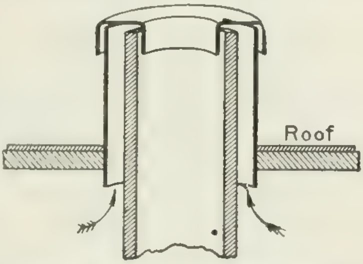


Fig. 149. Pipe Flashing Capped with V-Ring of Lead and Providing Egress for Warm Air from Attic.

Flashings. There are patent devices for flashing around pipes, usually made of copper; but the plumber will do well to command the skill necessary to manipulate sheet lead to suit conditions as he finds them. In any location where warm air will always be seeking an outlet from the attic through chance openings, the sleeve of the flashing may be made two to four inches larger than the outside diameter of the vent, and capped with an annular V-ring of lead in the manner shown in Fig. 149. The cap ring need only be tacked to the sleeve with solder. The top edge of the sleeve should be notched or some other provision for air-exit made, so as to insure constant changing of the air in the sleeve. If, on account of braces or projections necessary to hold the pipe rigid where it passes through the sheeting, it is inconvenient to let the sleeve extend below the sheeting as shown in the engraving, it may terminate at the roof line. If the building is a storage warehouse, or for any reason the attic will not be very warm, or conditions are in favor of cold air being drawn in through chance openings in winter, then the method of flashing and packing the sleeve with felt or mineral wool as shown in Fig. 150 should be employed. In all cases the vent and flashing must rise above the possible snow-level for flat roofs. The snow-level on a steep roof will be less, but drifts may obstruct the vent if left at the snow-level. Some latitude for

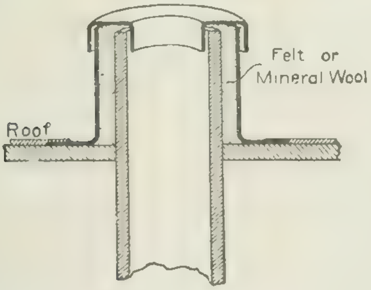


Fig. 150. Pipe Flashing Packed with Felt or Mineral Wool where It Is Desirable to Conserve Warmth in Attic.

settling of the roof under the weight of snow and ice, and for expansion of lines supported by brick piers or other supports far below the roof-level, must be allowed in fitting flashings. If they are too closely drawn or capped, trouble will soon follow.

To develop the pattern for a tapering sleeve for a vent for a flat or nearly flat roof, draw, as in Fig. 151, *XY* at random; set off *AB* equal to the altitude of the sleeve; then *AC* from *A*, perpendicular to *AB*; then *BD* from *B*, parallel to *AC*; let *AC* equal half the diameter of the sleeve at the top, and *BD* half the bottom diameter; then cut *CD* with a line crossing *XY*. Lines *AC*, *CD*, *DB*, and *BA* now outline half the elevation of the sleeve at the center. Next, with the intersection of *XY* and *CD* projected (*X* in the diagram) as a center, describe the arcs *EF* and *GH*. On *EF*, set off the circumference of the base of the sleeve *JK* (twice *BD* × 3.1416), and then indicate *JX* and *KX*. This develops the net pattern, and it remains only to add the necessary working edges to get, when cut out and formed up, a sleeve exactly conforming to the shape and dimensions required.

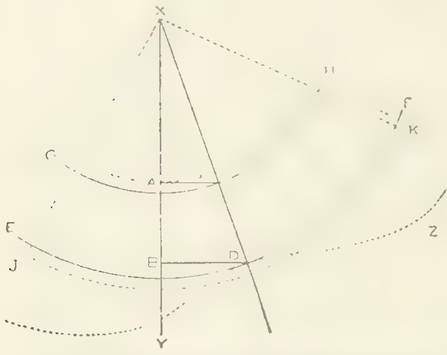


Fig. 151. Developing Pattern for Tapering Sleeve for Vent on a Flat Roof.

The development of a tapering sleeve for a pitched roof by strictly geometrical methods, is so intricate, and the springs and pitches of roofs so varied, that the plumber usually ignores—and is generally sensible in doing so—the true methods of cutting out such flashings. Lead is pliable; and in lieu of the more tedious method, flashings for pitched roofs are roughly laid off as follows, and then worked and trimmed to suit.

The circumference and curvature of the top edge and lines of the ends to be joined, are obtained by full-size diagrams in the same way as for a sleeve for a flat roof, shown by Fig. 151. The circumference of the top edge is, in this case, set off on GH, because the bottom, corresponding to *JK*, is unknown. The elevation *A B C D* is made just as though a sleeve was to be made for a flat roof, with the tapering side equaling *CD*, Fig. 152, which should be laid out to represent the elevation of the sleeve desired. The pattern diagram (Fig. 151) should be so drawn as to throw line *XCD* about the center or neck of the pattern, so as to bring the seam on the low side and thus present solid metal to the flow of water down the roof. The line of dots marked *Z* in Fig. 151, approximately outlines the bottom of the pattern. The cross-mark guides by which to draw the bottom of the flashing, are seldom more than five in practice, and their positions are determined in this way: *JX* and *KX* of the pattern diagram are extended and set off from the *GH* line equal to *XK*, Fig. 152. This gives the actual seam length for the low side of the flashing, as would be indicated if *XJ* and *XK*, Fig. 151, were extended to cut the extremes of the cross-mark guide line. *CD* of both the elevation and pattern diagram being equal, *CD*, Fig. 151, equals the length of sleeve in the neck or upper side. For the length of sleeve at the sides, half way between the neck and seam, produce dotted line K^1Y, Fig. 152, parallel to *CX*, to a point where it will intersect the roof-plane at the center of the pipe space. K^1X will then be equal to the required side lengths of sleeve, and may be set off on the pattern diagram by projecting radii from *X*, cutting the pattern midway between *C* and the seam lines, and setting off the distance XK^1 on these radii, measuring from the *GH* line. These specific points are a sufficient guide for laying out the bottom in any ordinary case.

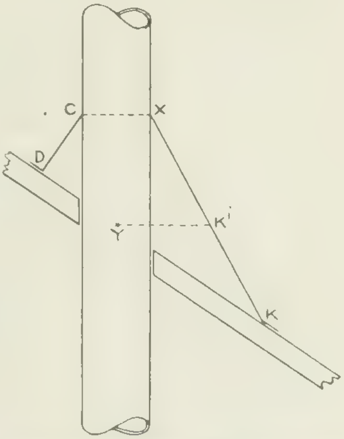


Fig. 152. Elevation of Tapering Pipe-Sleeve for Pitched Roof

Trap Ventilation. Needless multiplication of soil and vent connections may lead, in some cases, to conditions fully as deplorable as any that would follow the primitive simplicity of olden times. There are, however, certain principles that must be carried out to secure a perfect working job. These have often been curtailed by the extremists of one class, and always at the expense of the quality of the work. It is the extremists who regulate progress and keep things at a reasonable mean. The extremists in progression would drag us into practices perhaps unsafe; while their opposites, derisively termed "old fogies," hold us back, sometimes on untenable ground. The result is that the conservative element is the safest class to follow; it neither discards a well-tried method nor embraces a new one, without good reason to sustain the action.

As before intimated, the change in character of buildings and mode of life has necessitated a maze of pipe work in some buildings, which to the uninitiated looks like a senseless network thrust on the owner to the pecuniary gain of the plumber. This is not the case, however, as every plumber well knows; and there is no better way to disarm this type of credulity than for the plumber to be well versed in the philosophy of his business.

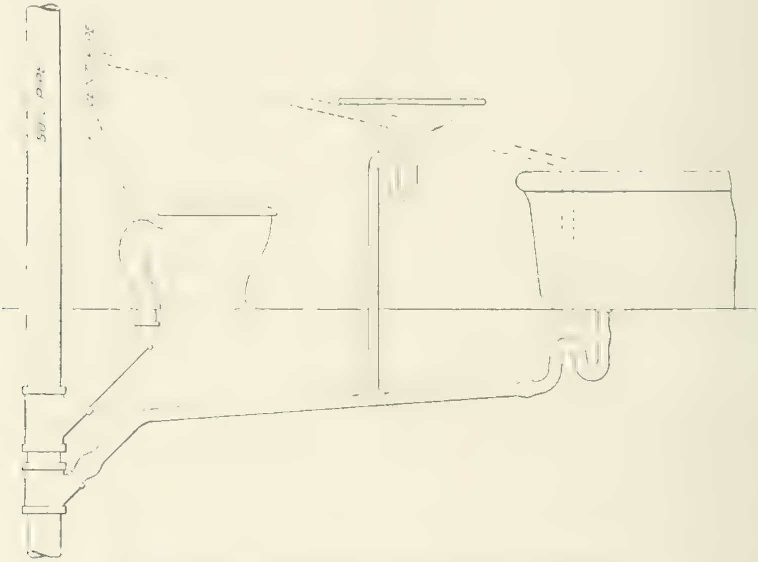


Fig. 153. Common Form of Crown and Stack Ventilation

The familiar cry that crown ventilation of traps destroys the seal by evaporation, is often but the echo of the voice of a man with an axe to grind. The deep-seal trap costs but a trifle more than the ordinary. There are also positive mechanical means—comparatively cheap, too—of protecting a vacant or unoccupied house against sewer air. In occupied houses, there is no chance for traps to lose the seal by evaporation; and, when properly piped, the evaporation of seals does not take place so fast as might be supposed. The crown vent is merely, or should be, to keep the water from being siphoned out of the trap. It is the practice of making the crown vent do duty not only as a siphon-preventer but also in the capacity of a stack vent, that has created the impression as to rapid evaporation.

If we bring a branch waste to a fixture just as though it was to be a "dead-end" connection, and then put in a liberal crown vent continued to the roof, as shown in Fig. 153, we have filled the letter of most specifications, because we then have *crown ventilation* and *stack ventilation*. But this is not the spirit of the work specified, nor is it up to the standard of intelligent workmanship. The current to the roof passes up the trap leg, and thence through the crown vent directly to the open, being brought on its way in close proximity to the seal of the trap; and it is no cause for wonder that such a connection would

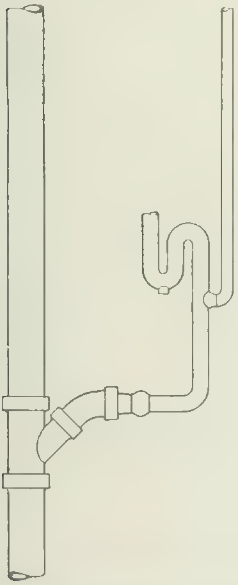


Fig. 154. Prevention of Siphoning Thwarted by Improper Placing of Vent Connection

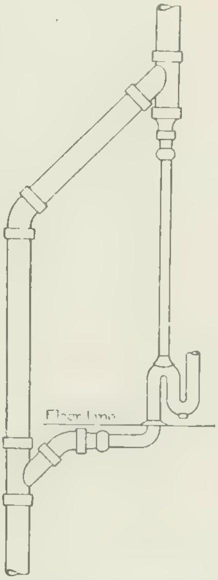


Fig. 155. Waste Stack Connected to Vent Stack above Highest Fixture.

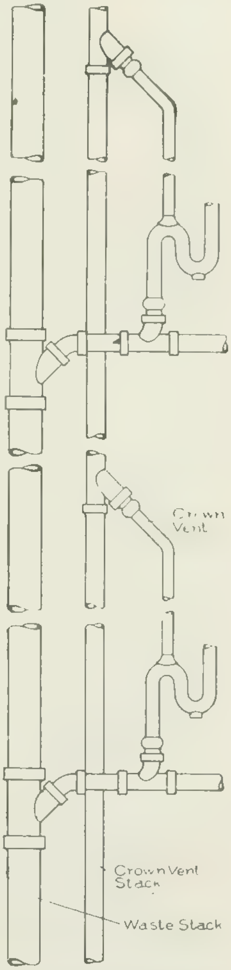


Fig. 156. Crown Vent Stack and Waste Stack Standing Close Together Giving Loop Effect in Pipe Ventilation

rob an ordinary trap of its seal within a surprisingly short time, if the fixture is left unused. This is the type of installation found in the wake of speculative builders, scrimping plumbing contractors, and ignorant or unscrupulous journeymen. Many examples of this double-duty vent pipe are seen, in which the workman foresaw the result to some extent, and, in attempting to counteract the supposed ills of evaporation, made the vent useless as a siphon-preventer by connecting the vent 10 inches or more below the crown of the trap, as shown in Fig 154. The proper way is to make both the waste and the crown vent branches from other lines. Of course, if it is the top fixture, or there is only one on the line, the waste stack may end in the beginning of the vent stack or connect into the vent stack, as in Fig. 155, according to circumstances. The main current goes by the most direct route—up the main waste and vent stacks of the string. If the crown vent and waste stacks stand close together, as in Fig. 156, we have the loop effect before spoken of; and with the fixtures near the stacks, the waste and crown-vent connections are both short—which is proper. It is poor practice to have the stacks far away from the fixtures, because one is then likely to fall into the error of allowing the crown vent to act also as a direct line vent for the branch waste. This plan is such a short-cut to accomplishing the work of roughing-in, that the temptation to err is great. If the waste stack cannot come near the fixture, then follow the loop principle, and turn up and into the vent stack, branching the trap into the waste branch, and taking the crown vent into the vent stack, as shown in Fig. 157, or into a vent continuation of the branch waste, as preferred. If neither main stack can come near the fixtures, then loop out from the soil or waste stack to the fixture, and back into the main vent, leaving enough upright

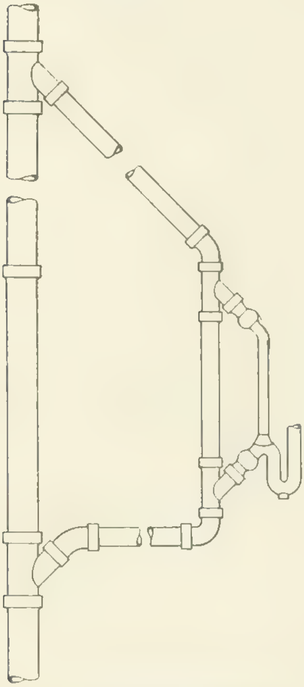


Fig. 157. Method of Securing Loop when Waste Stack is not Near Vent Stack

pipe at the fixture end of each loop to branch the waste and crown vent into, as illustrated in Fig. 158. In this way, half of the branch loop acts as a waste, and half as a vent, and there is ventilation through the soil or waste branch part without continually pulling the air into juxtaposition with the trap seal. Also, the local branch waste to the trap and the crown vent pipe are thus permitted to be as short as desired.

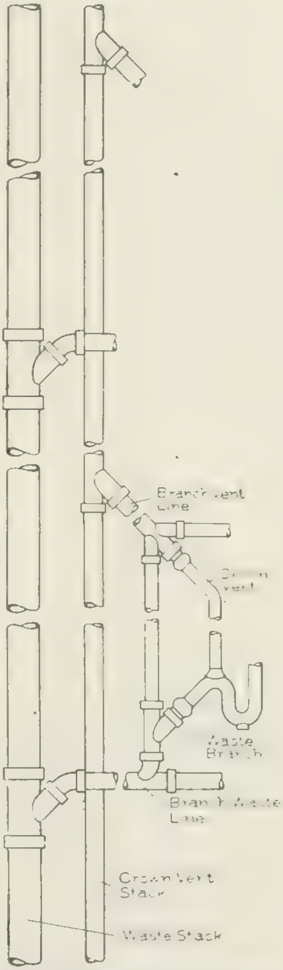


Fig. 158. Method of Ventilating Pipes where Neither Waste Stack nor Crown Vent Stack are Near the Fixture.

To avoid separate stacks for scattered fixtures, what is termed the *continuous system* of soil pipe is frequently employed when practicable. This means offsetting the main so as to be able to include all the fixtures of a toilet-room without making long branch wastes. If vent lines are also offset in this manner, some provision for water-washing the offset should be made, as the products of corrosion or other foreign matter might otherwise fall into and choke the bend at the foot of the upper vertical part. Especially is this true when plain wrought pipe is used. Lavatory wastes are generally used to wash vent lines in such cases.

Some city ordinances permit the continuous system practically without vents, merely requiring the fixture connections to be not over 3 feet in length, and requiring either vents or non-siphoning traps where the stack cannot be brought within reach of the 3-foot limit placed on branch connections.

A plan of offsetting, some modification of which may be used in any kind of system is shown in Fig. 159, which makes plain the work of offsetting soil waste and vent lines without incurring the risk of having trouble with the vent pipe sooner or later. It provides for throwing the corrosion of the vent line, both above and below the offset, into the soil line, where it will be washed into the sewer by the water discharged from the closets and other fixtures. By simply offsetting the vent line, the corrosion from the pipe above the offset will fall into the bend, drift out into the horizontal part slightly, and finally choke up the horizontal vent altogether. As shown by the engraving, commencing with the main soil line at the first fixture, a branch line is made, and the *branch* then becomes the main soil line, leaving the vertical part for the vent. Next comes the offset, and after that another branch line for soil fixtures, again leaving the vertical pipe for the vent, so that whatever falls down the, vent, either above or below the offset, lands in the soil pipe and is carried away with the water. With this arrangement, the only possible chance for the vent to clog with corrosion is in the horizontal part of the vent offset. What corrosion takes place in a piece of horizontal pipe, is not sufficient to warrant consideration in itself. There is no other corrosion to be taken care of, except that which forms in the few feet of vertical pipe between *A* and *B*, which will not be enough to restrict materially the area of the pipe. It is best to make the piece of pipe between *A* and *B* as short as possible.

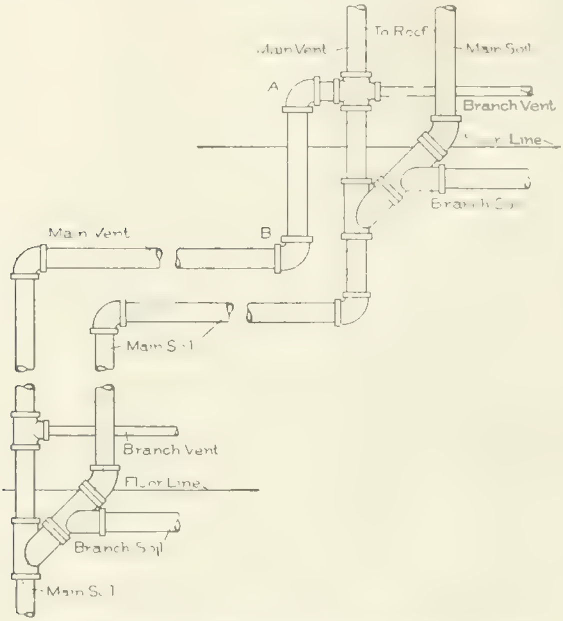


Fig. 159. Method of Offsetting Soil Waste and Vent Lines

With the continuous system, several offsets, simple or more or less complex, as shown in Fig. 159, may be necessary in the same stack, according to location of fixtures and the scheme of venting and trapping. Fig. 153 shows a group of fixtures piped diametrically opposite to the continuous stack idea. The main stack does not deviate in favor of odd fixtures. Regular open wall-traps are used. The crown vents are assembled into one stack, and carried up independently or into the stack above the highest fixture. As before stated, the plan shown in Fig. 153 is faulty in that it favors evaporation of the trap seals by putting the extra duty of a line-vent current on the siphon or crown-vent branch.

Anti-siphon traps often simplify ventilation problems, especially in awkward situations where it would be very difficult to vent a fixture properly with pipe. Fig. 160 illustrates an example of this kind, in which non-siphoning traps are used on bath and lavatory without any form of crown or branch line vents. In good practice, bath traps are placed convenient to reach, having screw-top hand-hole with cover in full view at the floor-level.

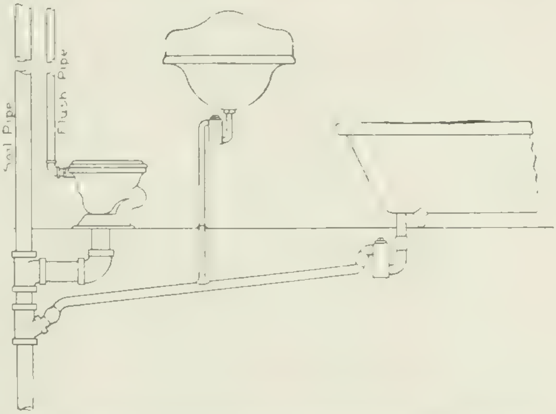


Fig. 160. Anti-Siphoning Traps Dispensing with Necessity for Vent Lines

Soil Stacks. The size to make a soil stack is largely a matter of opinion. There are examples of 10-inch stacks serving 40 closets with the usual complement of lavatories and urinals. There are also instances where as many as 75 closets and numerous other fixtures all discharge into a 5-inch stack which has never given any indication of being too small. Although common usage requires a 4-inch soil stack, there seems little advantage in adhering to this dimension in small and simple installations. When the plumbing was designed for the city of Pullman, Ill., more than twenty years ago, 3-inch soil stacks were used for small dwellings, and in some cases they were placed in a party wall, so as to afford service for two adjoining houses. The plumbing regulations of Washington, D. C., have allowed for some years past the construction of 3-inch soil stacks for dwellings having only a single bathroom, and the practice has been justified by favorable results. When it is considered that the outlet of a closet is rarely more than 2½ inches in diameter, it appears that a size smaller than 4 inches is often allowable.

The size does not increase with the number of fixtures. Very few of a hundred closets in a building would ordinarily be flushed simultaneously. A 5-inch stack would answer well for 100 closets in a tall building where the toilet-rooms are superimposed, as shown in Fig. 161, which outlines the soil, waste, and vent pipes of several groups of fixtures, rain-water leaders, etc. If the same number of closets were at one elevation, and the fall only moderate, common sense would dictate a 6, 8, or 10-inch line, with 4-inch fixture branches.

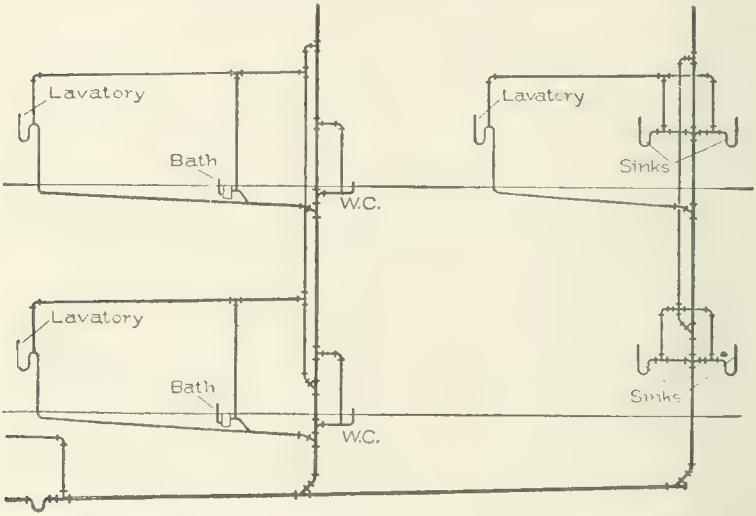


Fig. 161. Showing Layout of Soil, Waste and Vent Pipes of Several Groups of Superimposed Fixtures in Same Building.

The velocity with which the water will flow away should be a prime factor, but sizes in soil and waste pipes are far more a matter of empiricism than in supply work. A soil pipe not too large is self-scouring in a sense. This point is erroneously argued in favor of small waste pipes. If a soil pipe too small for the duty should be installed, ordinary usage would develop the fact quickly. But in a waste outlet, where grease is likely to accompany the water, a pipe large enough to carry the waste easily when the pipe is new, may become choked after a considerable period of time, and merely because it is of the size so-called "self-scouring." A house line which may be much too large for the waste will be likely to choke from floating matter adhering to the sides above the water line until overhanging ridges are formed that break down in the channel. Being too heavy for the water to push along, this matter acts as a dam, and complete stoppage soon results. This is why large sewers are built with elliptical bottom section. Having variable flows to take care of, the depth of water produced by ordinary usage cleanses the conduit, and keeps it in much better condition than if round conduits of the same capacity were employed.

Slope. With due respect for appearance, all the fall possible should be given lateral soil and waste lines. About $\frac{3}{16}$ inch to the foot (one degree) is taken as the minimum. With cast pipe and leaded joints, much more than this can be given, by gaining change of direction in setting the joints. With screwed fittings for wrought pipe, tapped, pitched one degree from the nominal angle, less latitude to vary the fall is offered. Considerable variation is possible, however, by cutting pitched threads on the pipe. In positions where the cutting of one pitched thread entails the work of cutting another with the pitch just opposite that of the first in order to follow the perpendicular again, the work is irksome and is seldom resorted to. Cast fittings, threaded, for drainage work, are recessed in the ends, so that, when screwed on the pipe, the pipe and interior of the fitting are of the same diameter, thus presenting no jog or broken edges to favor stoppage. Stoppage of drains of any kind is likely from many causes; and during installation, trap-screw ferrules, or tees with brass plugs, according to the kind of pipe being used, should be provided along the line, as

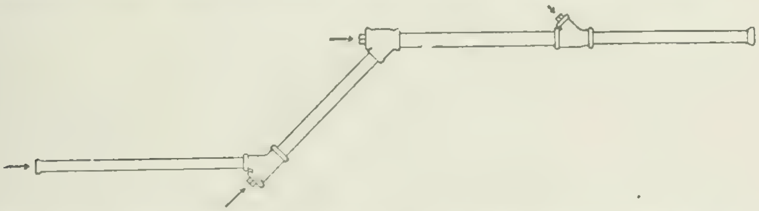


Fig. 162. Trap Screw Ferrules Installed at Intervals to Facilitate Cleaning of Drain Pipe.

shown in Fig. 162, so as to make the work of cleansing as convenient and inexpensive as possible.

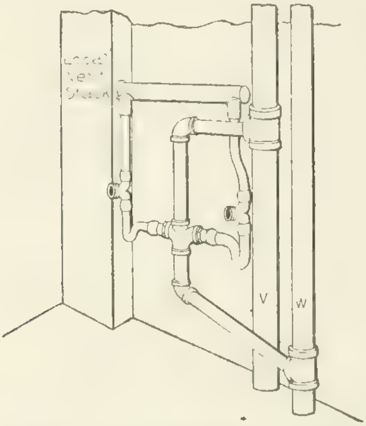


Fig. 163. Local Ventilation for Two Urinals.

Sizes of Soil and Waste Pipe. The usual sizes for soil and waste work are: 5-inch for ordinary house main (horizontal); 4-inch for 1 to 4 closets; 5-inch horizontal branch from 5-inch stack for a battery of five or more closets; 5-inch stack for any ordinary number of fixtures; main vent stack, same size as soil-stack; loop vent, same size as stack; crown-vent stacks, 2 or 3-inch; slop-sink stacks, 3 or 4-inch; closet connection, 4-inch; closet crown vent, 2-inch; slop-sink connection, 3-inch; slop-sink vent, 2-inch; urinal stacks, 3-inch; urinal branch wastes, 2-inch; urinal trap vents, 1½ to 2-inch; bath stacks, 3-inch; bath-waste connection, 2-inch; lavatory wastes, 2-inch. The 2-inch refers to the size of cast pipe used in the case of lavatories and baths; the lead trap and connections of these, and often of other fixtures, are made 1½-inch. Small lavatories often have 1¼-inch waste. The crown vent is usually one size less than the trap for all but closets and slop sinks. Of late, bath-waste outlets are frequently made 2-inch. Kitchen-sink stacks are made 3-inch; single sinks or branch waste for one sink or set of trays, 2-inch, with 2-inch trap and 1½-inch crown vent.

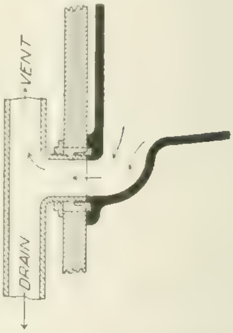


Fig. 164. Part Section of Locally Vented Urinal and Connection.

Local Ventilation. A local vent is a pipe leading air from the bowl of a closet or through the outlet of a urinal to carry away odors with a current of air fed by the air of the room. In Fig. 163 are shown two openings for urinals where the roughing-in provides for local ventilation for the urinal bowls in a way that is equivalent to the local vent pipe to a closet bowl. *V* is a general vent stack, and *W* the urinal waste stack. Instead of putting in crown vents for the traps, the branch waste becomes a vent at the junction of the trap branches, and loops back into the general vent stack. There is sufficient ventilation in this case for two reasons—the traps are close to the line; and the current up the main local vent stack is induced and maintained by a fan motor, which, in drawing the odors from the urinal bowl, creates more or less suction on the house side of the trap seals and counteracts the tendency toward siphonage on the sewer side. The roughing-in shown, is hid by marble slabs in the finished work.

A section of the marble back, with urinal and vent and waste connection, is shown in Fig. 164, which makes clear what is meant by local urinal ventilation. The difference between it and local closet ventilation, is that as the trap for the urinal is not in the urinal proper, the current from the room passes through the urinal outlet except while it is flushing; while in the closet the local vent connection is made to the bowl above the visible water-level, because the trap below interferes with connecting it otherwise.

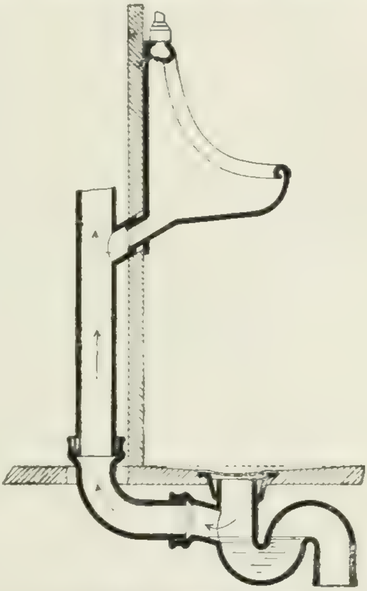


Fig. 165. Locally Vented Trap for Urinal and Floor Drain Combined.

Another plan of local-venting a urinal is shown in Fig. 165, in which the urinal trap answers as a trap to the floor drain as well, and the local-vent current passes down through the grating of the floor-slab drain and up through the urinal waste to the point where the urinal proper connects. Between the trap and urinal connection, the pipe is a waste and local vent combined, its continuation above the urinal vent connection being simply a local vent pipe, the area of which being equal to the combined area of the urinal outlet and floor-slab grating, a current also passes from the urinal bowl through its outlet into the local vent pipe. The only fault to be found with this arrangement is the abnormal distance of the trap from the fixture, which, however, is of little consequence so long as the means for producing a current in the local vent stack is doing its duty. Fig. 166 shows the openings left for a battery of closets that are to be set on a

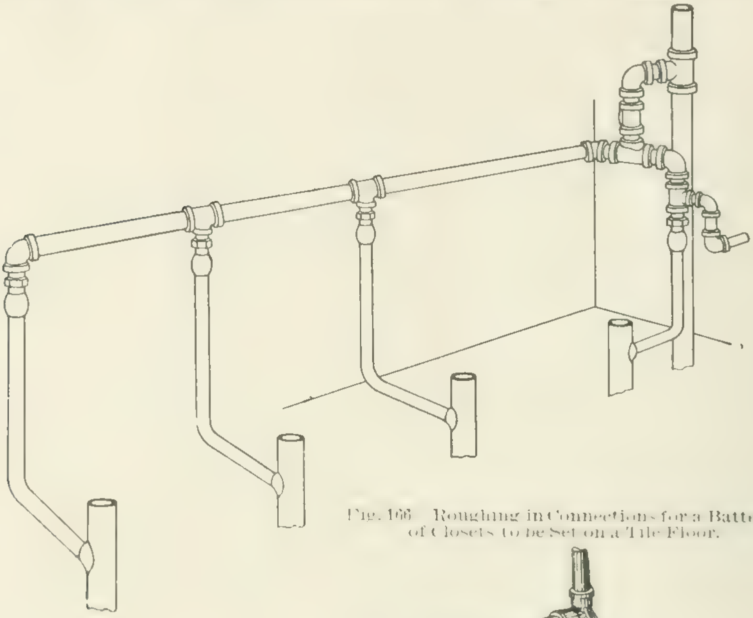


Fig. 166. Roughing in Connections for a Battery of Closets to be Set on a Tile Floor.

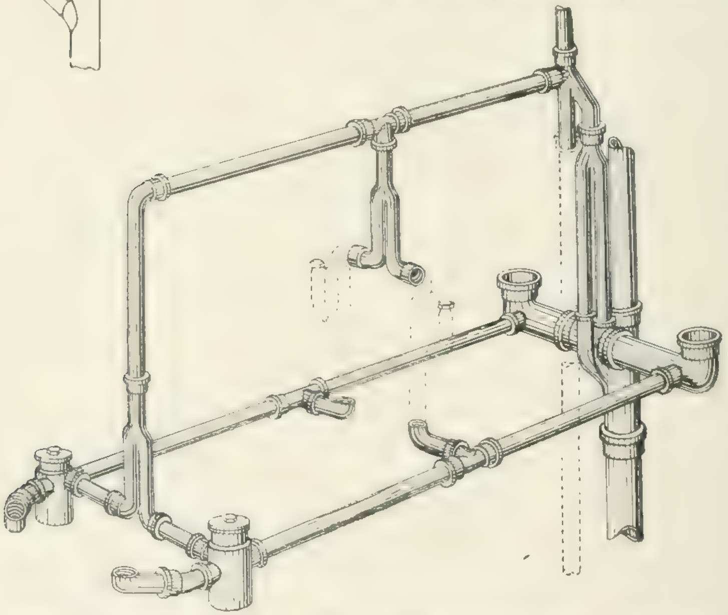


Fig. 167. Roughing in for Adjacent Toilet Rooms on Same Floor of Double Flat Building.

tile floor. The uprights connect into a branch soil line below. The illustration is given to show a system of venting which can be used with closets that do not permit of crown venting.

Local vent stacks are round or rectangular, and are made of galvanized sheet iron. Unlike the soil or supply pipe system, the stack system is made proportional; that is, the area of the stack at any point is an approximation to the aggregate area of all the vent branches that have been connected into it up to that point. The local vent stack is sometimes carried into the same shaft which incloses the smoke-pipe from the boilers. In other cases it is connected

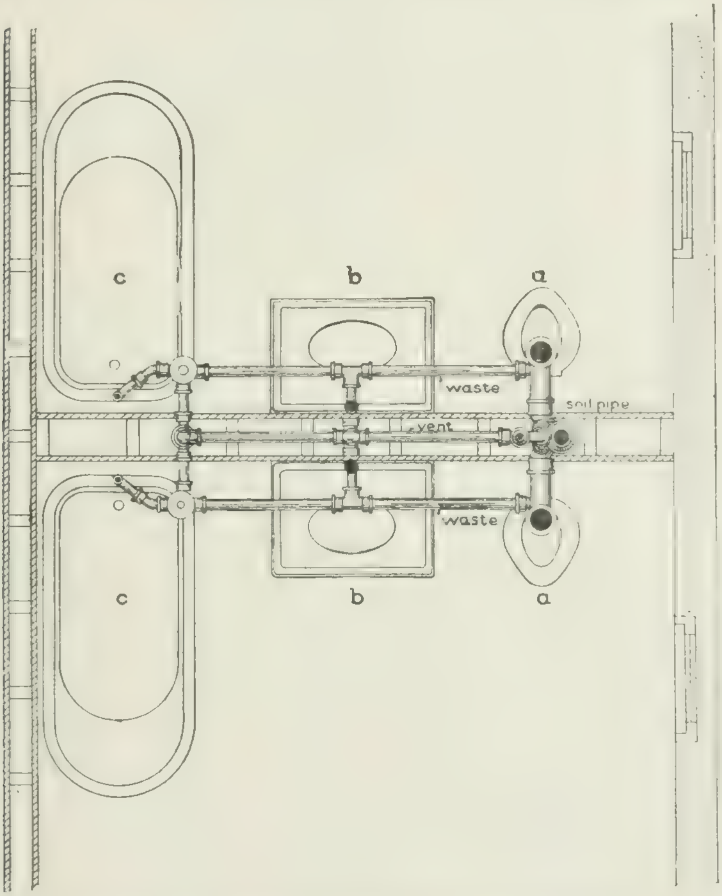


Fig. 168. Plan of Complete Installation Shown in Part in Fig. 167

with an exhaust fan driven by power, usually supplied by an electric motor, thus insuring a constant air-current. Bowl or local ventilation is not generally installed in dwellings. The closet does not receive such frequent usage in private houses as in larger buildings such as hotels, offices, etc.; and in the smaller structures there is no hot flue that can be depended upon for purposes of aspiration. If led to the open air, the vent will act very well in warm weather; but during the winter months it will be likely, through reversal of the current, to bring in cold air and disseminate the odor through the apartment.

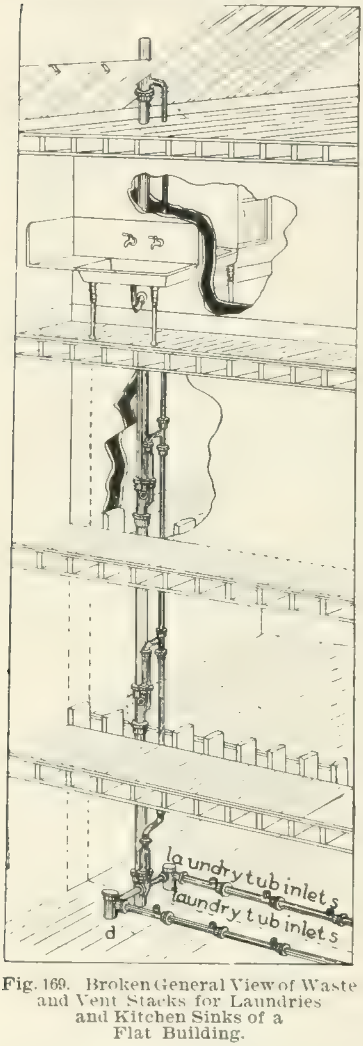


Fig. 169. Broken General View of Waste and Vent Stacks for Laundries and Kitchen Sinks of a Flat Building.

Soil Pipe and Fittings. Under the head of *specialties*, many forms of patented soil-pipe traps and fittings have been placed on the market from time to time, with a view to lessening labor and cost and simplifying the work of roughing-in for plumbing fixtures. Of these, a singular instance of the use of one type will be noticed. Fig. 167 illustrates a well-known line used in roughing-in for the toilet-rooms of a double-flat building. Being drawn in perspective, the function and merit of every fitting shown is self-evident. Fig. 168 gives in plan view the roughing-in shown in Fig. 167. The location of the fixtures on the floor below the plan of piping, is indicated in solid lines by *a*, *b*, and *c*. On other floors, corresponding fixtures for the stack shown, are of course superimposed as a matter of economy and convenience. Fig. 169 is a broken general view of the waste and vent stacks for the laundries and kitchen sinks of the same building, the roughing-in work and some of the fixtures being shown. The regular standard soil-pipe and fittings can be made to answer for any case, although inconvenience and additional expense are often incurred in working fittings of standard dimensions in close quarters.

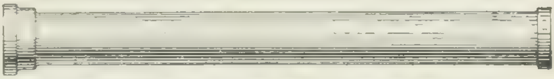


Fig. 170. Single-Hub Length of Standard Soil-Pipe

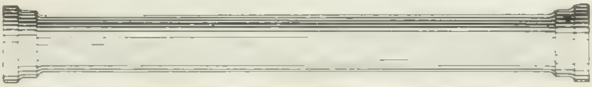


Fig. 171. Double-Hub Length of Standard Soil-Pipe

There are several weights of soil pipe and fittings used, varying with the building or with the requirements of city or state sanitary laws, etc. The weight known as *standard* is sometimes used on buildings under four stories in height, and for vent pipes and soil-pipe extensions above the highest fixture. Extra heavy pipe and fittings are used in tall buildings and in most ordinary work, for all soil and waste purposes below the highest fixture. The standard length of soil pipe for all diameters, is five feet, exclusive of hub.

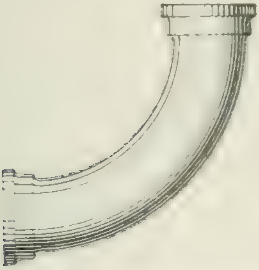


Fig. 172. Quarter-Bend with Double Hub.

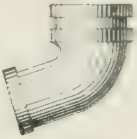


Fig. 173.

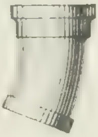


Fig. 174.

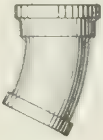


Fig. 175.

Short-Radius Bends for Soil-Pipe

Fig. 170 shows a regular single-hub length. Fig. 171 represents the double-hub length employed to avoid the use of double-hub fittings and extra joints where less than full lengths are required in cases where the cost of regular extension pieces would exceed the price of double-hub pipe. Fig. 172 is a quarter-bend with double hub. It is of the long-sweep or long-radius pattern. The whole list of standard regular fittings is made in the long-radius pattern. They should be used where possible; but the shorter-radius type, corresponding to that shown in Figs. 173 to 180, is most generally employed because the little room available enables the plumber to lay lines in places where cramped conditions make the use of the long radius impossible.

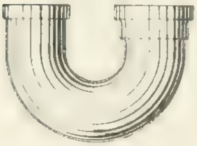


Fig. 176. Return Bend for Cast Soil-Pipe.

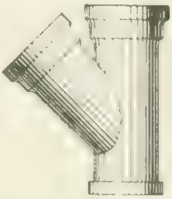


Fig. 177. Single Y.

One-sixteenth, one-eighth, one-sixth, one-fourth, and return bends embrace the regular list of soil-pipe bends, giving a range in angles from $22\frac{1}{2}$ to 180 degrees in the same plane; and, by winding them, giving a twist to the joints, almost any angle with the original direction can be obtained.

A wider range of bends is offered in the recessed and threaded cast-iron drainage fittings for use with wrought pipe. Omitting the *pitched* ells and tees for regular fall, $5\frac{5}{8}$ degrees is the most obtuse fitting regularly made.

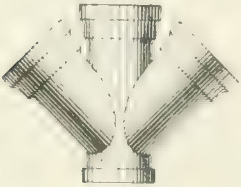


Fig. 178. Double Y Branch.

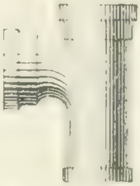


Fig. 179. Sanitary Tee.

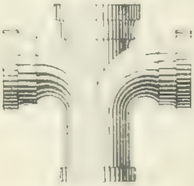


Fig. 180. Double Sanitary Tee.

The return bend for cast soil-pipe is represented by Fig. 176; single Y, by Fig. 177; double Y-branch, by Fig. 178; sanitary tee, by Fig. 179; and the double sanitary tee, by Fig. 180. The tee and double tee shown are known as the *sanitary* pattern, on account of the

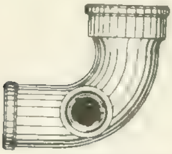


Fig. 181. Quarter-Bend with Side "Outlet."

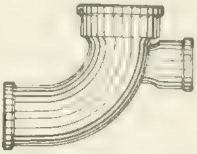


Fig. 182. Quarter-Bend with Heel "Outlet."

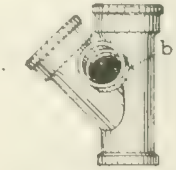


Fig. 183. Single Y with Side "Outlet."

curved branches, which direct the flow in the pipe line somewhat in the same manner as does a Y-connection. Common tees and crosses are made in strictly right-angle branches. The ¼-bend is also made with right and left side-outlet, as indicated by Fig. 181; and with heel-outlet, as shown in Fig. 182. Tees, crosses, and Y's can be had with side outlet as shown at *b*, Fig. 183. These auxiliary openings, while always termed *outlets* by the trade, are in fact *inlet* branches. Long branch fittings, with a branch equivalent to a Y and ⅛-bend connection, are also made.

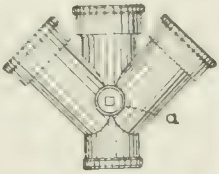


Fig 184 Double Y-Branch with Trap-Screw Clean Out.

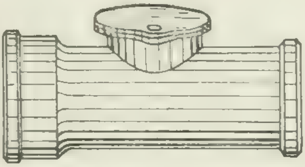


Fig. 185. Bolted-Plate Clean-Out on Soil-Pipe.

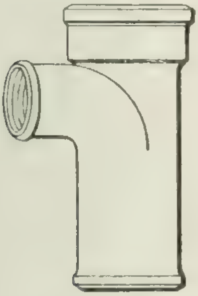


Fig. 186. Cast Soil-Pipe with Threaded Branch to Connect to Wrought Pipe.

Offsets may be had to offset the pipe as little as half of one diameter, and up to six diameters. Any of the standard branches can be had with trap-screw clean-out, as shown at *a*, Fig. 184. The bolted-plate clean-out, indicated in Fig. 185, is undesirable, as the cover can rarely be securely replaced when removed for purposes of cleaning. A series of cast soil-pipe fittings are made with branches threaded for wrought pipe, as shown in Fig. 186. These meet the demand for a means of easily connecting wrought vent-pipes to a cast-iron pipe line. Similarly, combination lead and brass soldering nipples threaded for wrought pipe are now carried by supply houses, the lead being furnished straight, as shown in Fig. 187, or in the form of a quarter-bend. These are very convenient for use with wrought vents, and are equivalent to the regular combination lead and iron

Fig. 187. Combination Lead and Brass Soldering Nipple Threaded for Wrought Pipe.

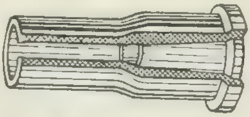


Fig 188. Combination Lead and Iron Ferrule, "Raymond" Type.

ferrule, shown in Fig. 188; they can be used with cast pipe by calking-in. This combination ferrule—commonly known as a "Raymond" ferrule, from its maker—is sometimes damaged during the process of calking; and sometimes the outer covering is burned through in making the solder joint. For these reasons, its use is prohibited in many localities.

Brass ferrules for calking-in make a better job than lead and iron; but in case of their use, it is necessary to wipe on a piece of lead, which in cramped connections is sometimes most inconvenient; and both the ferrule and the work are more expensive.

The recessed or hub ferrule shown at *b*, Fig. 189, is a good form of ferrule. It is not satisfactory, however, as usually sold. The stock length brings the increase in diameter necessary for the recess close to the face of the hub of the fitting, making it very difficult to yarn and calk, even before the lead pipe is wiped on; and as these joints are usually wiped before the ferrule is calked in place, it is difficult to make safe joints where they are used. The forms of brass ferrule generally used are shown at *c* and *e*, Fig. 189, the lead end of *e* being contracted for use with 1½-inch pipe or less.

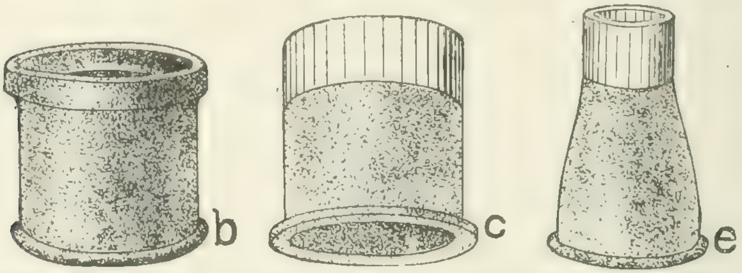


Fig. 189. Brass Ferrules—*b*, Recessed or Hub; *c*, Straight; *e*, with Lead End Contracted to Make Joint with Smaller Pipe.

Soil-Pipe Joints. A section of a soil-pipe joint is shown in Fig. 190. The materials used in making these joints are good, clean hemp or oakum, with melted lead poured in and afterward calked. The packing to support the lead should be of uniform strand, evenly twisted. When a joint is made with pipe cut to length, the bead having been cut off the spigot end, care must be taken to pack the yarn uniformly tight without driving it through into the bore of the pipe, and in a way to keep the spigot end in the center of the hub space so as to get a uniform thickness of lead on all sides. As an extra precaution in difficult places, the packing is sometimes dipped in linseed oil, and then wrung as dry as possible, before yarning a joint. This gives almost positive assurance that the joint will not leak water. Likewise, shavings of sperm candle whittled in on top of the yarn before pouring the lead, prevent water leakage.

Some plumbers pour in just enough lead to make a ring around, and calk it down reasonably tight on top of the yarn, before pouring the hub full. Unless very little yarn is used, this does not leave a solid ring of lead deep enough to insure the best joint; and if too little yarn is employed, there is danger of the lead burning its way through into the pipe. This method is therefore undesirable in either case.

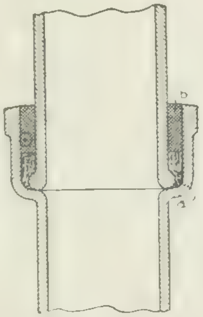


Fig. 190. Section of Soil-Pipe Calked Joint.

Care should be taken before pouring a joint, to see that no threads of yarn are standing above the face of the hub; otherwise a leak may result from stray threads protruding. Becoming charred by the heat of the lead, they soon leave a tiny hole through the lead, from which trouble results. No matter what the position of the joint, the entire charge of lead to complete it should be poured at one time, and the lead should be hot enough to insure a true union of the meeting edges. If the pipe is large or the weather very cold, it is better to warm the hub in order to insure the flowing edges uniting, than to risk pouring the lead so hot that it may burn through the packing.

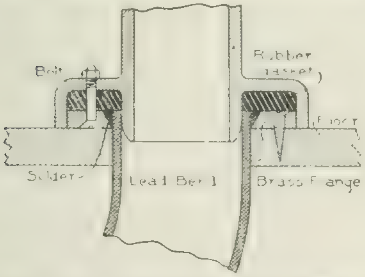


Fig. 191. Good Type of Closet Floor-Joint.

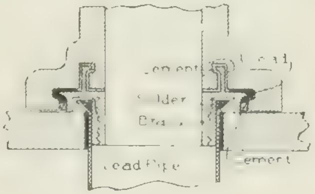


Fig. 192. Secure Type of Floor-Joint, for Closets which can be Revolved about the Outlet.

It is a matter of opinion, whether or not a joint should always be calked while it is hot. If the pipe is heavy enough to stand it without cracking the hub, it can make little difference whether the joint is calked hot or cold. If the pipe is light, a hard calking while the joint is hot and the hub expanded may cause splitting of the hub when it contracts from cooling. The best plan appears to be that of driving down the lead reasonably tight while it is hot and therefore softer than when cold, at which time it will give and adjust itself to the irregularities of the hub and spigot. Then, a little later, calk twice around with a thin-edge tool, driving the lead into contact with the spigot surface on one edge, and against the inner hub surface on the other.

Floor Joints. A closet floor joint of good type is shown in Fig. 191. In this joint, a bevel-edged brass floor-plate is screwed to the floor and well soldered to the end of the lead bend, as indicated. The floor-plate has slots for the closet bolts, so that any variation in the position of the bolt holes in the flange of the closet pedestal will not cause trouble when aligning the bolts, as they can be slid along in the slots of the plate to the required position. Common putty, plaster of Paris, or hydraulic cement may be used instead of a rubber gasket; but the latter two materials make it difficult to remove the closet from its setting, and there is always risk of breaking the flange if the pedestal has to be moved for any reason.

A secure type of joint, introduced a few years since, is shown in Fig. 192. This connection is well suited for such types of closets as can be revolved about the outlet, but cannot be used with closets where the outlet is well toward the rear of the fixture

TRAPS

Traps are made in many forms, none of which combines every desirable feature. A trap with vertical drop at the inlet is considered best for the main intercepting trap, as it allows the incoming water to break up the scum and floating matter so that it will be carried out promptly by the flow. This form also presents a difficult place for sewer rats to climb, and is therefore favored for that reason also.

In regular fixture traps, open-neck bends, and the least surface possible, are favored. The Y and ⅛-bend connections in one fitting, and other fittings combining the virtues of the open bends of long-radius fittings, are used merely because they offer little chance of stoppage; but traps should have every part exposed to view in order to betray leakage. Tide-water traps are usually nothing more than simple, large, swinging check-valves. Some intercepting traps are provided with a swinging check. The tide-water feature is necessary only when high water or tides are likely to raise the water into which the sewer discharges so as to flood the cellar through fixture openings.

Siphonage. Traps introduce into plumbing the element of *siphonage*. This may be normal and desirable, as in the case of closets which discharge their contents by siphonic action; but siphonage in fixture traps, and the means of preventing it, are prime factors in every plumber's work.

Ordinary siphonage can best be illustrated by a few simple diagrams showing the principles involved. In Fig. 193 is shown a U-tube with legs of equal length, filled with water. If we invert the tube, as shown in Fig. 194, the water will not run out, because the legs are of equal length, and contain equal weights of water, which will pull downward from the top with the same force, tending to form a vacuum at *A*. Cohesion of the particles of water, together with equal atmospheric support of the water at the open ends of the tube, prevents any appreciable void space when the U is of short length. If one of the legs is lengthened, as in Fig. 195, so that the column of water is heavier on one side than on the other, the water will run out. The atmospheric pressure being practically equal on both legs, the greater weight of the water in the long end, through cohesion, assisted by the air-pressure, pulls the water in the shorter tube up over the bend, much as an unbalanced chain would run over a pulley. The columns

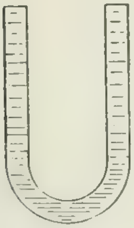


Fig 193. U Tube with Legs of Equal Length.

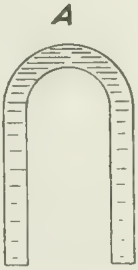


Fig 194. U Tube Inverted.

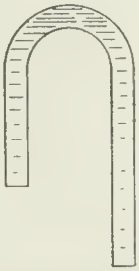


Fig. 195. Inverted U-Tube with Legs of Unequal Length.

of water in the tube in this case may be likened to a piece of rope hanging over a pulley; when equal lengths hang on each side, it will remain stationary; but if one end is longer and therefore heavier than the other, the whole rope will be drawn over by the longer and heavier portion.

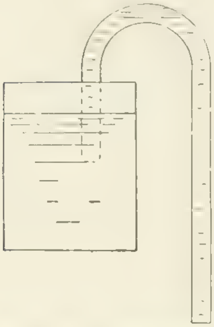


Fig. 196. A Common Siphon.

If the short leg of Fig. 195 be dipped in a vessel of water, as shown in Fig. 196, we then have the conditions necessary to form a common siphon. The atmospheric pressure, which before acted on the water at the bottom of the short leg of the tube, then becomes operative on the surface of the water in the vessel, and the flow through the tube will continue until the water-level in the vessel falls slightly below the end of the tube, admitting air and breaking the siphonic action. Gravity acts proportionally on the water of both legs of the U during siphonage, and the point of tension is therefore at the highest point of the bend.

If the bend should be pierced at the top, air-pressure would be established at both ends of each leg, and gravity would instantly empty the short leg into the vessel. It is in this manner that a crown vent to a common fixture trap breaks the flow and throws enough water back into the body of the trap to preserve the water-seal. Fig. 197 shows the principle of Fig. 196 applied to the trap of a plumbing fixture. If the bowl is well filled with water, so that when the stopper

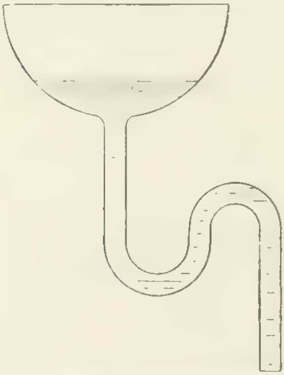


Fig. 197. Trap Fulfilling Siphonage Conditions.

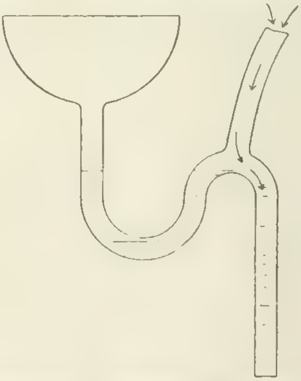


Fig. 198. Siphoning of Trap Broken by Crown Vent.

is removed from the bottom, the waste pipe for some distance below the trap will be filled with a solid column of water, siphonic action like that just described will take place and the trap will be drained. A sufficient amount of water runs down from the fixture and sides of the pipe above the trap to partially provide for the seal, its full restoration being assured when a crown vent is used, by water being thrown back from the short leg of the siphon (center leg of the trap) as shown in Fig. 198.

The direct action of the water of a fixture in breaking its own trap seal by siphonage, is called *self-siphonage*. A more common form of trap siphonage in defective work, is where two or more fixtures connect with the same waste pipe, as shown in Fig. 199. In such cases, the seal of the lower fixture is more apt to be broken by the discharge of the upper. The falling column of water leaves behind it a partial vacuum in the soil pipe; and the outer air tends to rush into the pipe through the way of least resistance, which is often through the trap seal of the fixture below The friction of the rough sides of a tall soil-pipe, even though it be open at the roof, opposed to the flow of air through it, will sometimes offer more resistance than the trap seals of the fixtures, with the result that the seals are broken, and gases from the drain are free to enter the building.

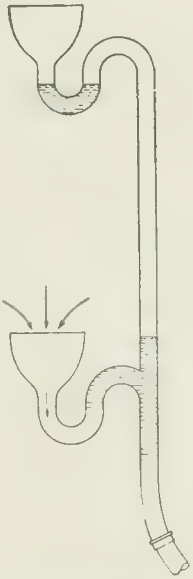


Fig. 199. Two Unvented Fixtures Connected to Same Waste Pipe, Causing Self-Siphonage.

Kinds of Traps. The kinds of fixture traps are innumerable. They can be divided into two general classes—those that seal with *water only*, and those that have a *mechanical seal* as an adjunct to that of the water. These may be again divided into *plain* and *anti-siphoning* classes.

The trap having no concealed partitions and with all its walls exposed to view, is best. If the water leaks through the wall, its defectiveness is evident, and the annoyance from the leak suggests repairing.

Of the simple *water-seal* fixture traps, the open-walled *drawn lead* is used for ordinary work. It can be had with equal-length arms or with extended inlet or outlet, so as to reach from fixture to floor or wall without a piece of intermediate pipe. The form shown by full lines in Fig. 200 represents a full "S" pattern. When the ends are bent as per dotted lines *A* and *C*, the trap is called a *running* trap; when the ends are at *D* and *C*, it is said to be a *half-S* or *P* trap; when the ends are set as at *D* and *E*, it is called a $\frac{3}{4}$-*S* trap. *F* is a clean-out screw for emptying and cleansing. The distance represented by *X* should, in a trap for ordinary purposes, be $\frac{1}{2}$ to 2 inches, according to size. Frequently this distance, which constitutes the water-lock, is much reduced; and sometimes the trap is unsealed by the plumber stretching its bends in order to reach some faulty roughing-in.

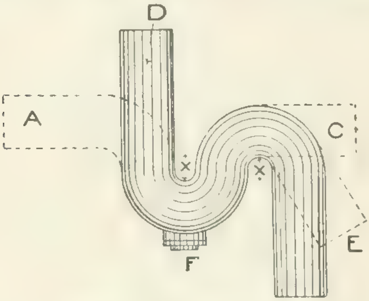


Fig. 200. "S"-Pattern Trap.

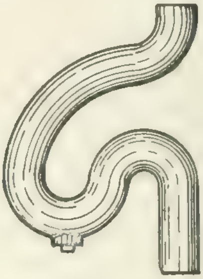


Fig. 201. A Bag Trap.

In buildings where the plumbing may be left unused for weeks from time to time, as is likely in rented houses, *deep-seal* traps, or those with mechanical seals also, should be used. This point is not so important in detached houses or those rented to one family only at a time, since, when a family moves out, there is no one to suffer. But in flat buildings, where some of the flats may be vacant for a time sufficient for an ordinary seal to be broken while other families are living in the house, deep-seal traps are more essential.

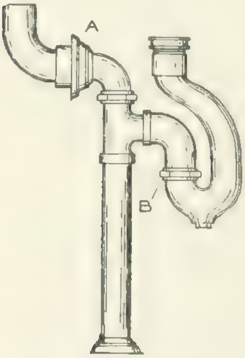


Fig. 202. Open Wall Trap, Partly Cast.

Fig. 201 shows what is termed a *bag trap*, made to bring the inlet and outlet in the same vertical line. These traps are interchangeable with any others with straight-line outlet—for instance, as shown in Fig. 204.

An open-wall trap partly cast and partly tubing, generally made of brass, is shown in Fig. 202, the vent connection to wall being at *A*. This form of trap generally has a swivel-joint at *B*, which is below the water line, so that the body may be swiveled to meet roughing-in openings in any direction within two diameters of the line of fixture outlet. The bag form shown is most convenient for D-shape or standing waste bowls which present the outlet comparatively near the wall. The regular "S" of this type suits bowls with center outlet, and will reach a wider range of variation in roughing-in.

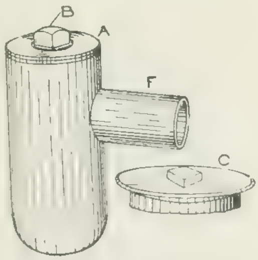


Fig. 203. Common Lead Drum or Pot Trap.

Fig. 203 shows a common lead drum or pot trap, most convenient to the plumber. It is furnished without openings, and the plumber makes bends, and wipes-in his inlet and outlet at points in the circumference most convenient to reach the fixture opening. *A* is the screw-top clean-out; and *B*, the wrench-face for turning it. The trap is furnished, when desired, with nickel-plated brass flanged cover, as shown at *C*, to screw on at the floor-level. *F* is ordinarily the outlet, the inlet being wiped-in near the bottom to give it the water-lock. This is not proper, however, as it puts the sewer air against the clean-out cover, which might leak gases into the building without betraying any evidence of its defectiveness by water leakage. To be strictly correct, *F* should be the inlet; and the outlet, in the shape of an offset, or that of an inverted P-trap without the trap-screw, should be wiped-in near the bottom in a way to retain the proper seal and thus bring the sewer air against the water-seal instead of the clean-out cover.

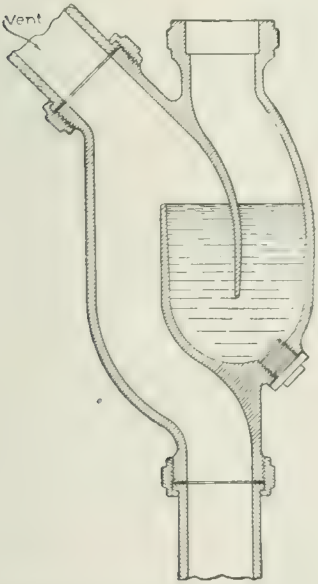


Fig. 204. Section of Flask or Atlas Trap, with Two Interior Weirs.

Traps that retain their seals by means of interior weirs are of doubtful character, even at their best; none but well-tested cast-brass traps of such a pattern should ever be installed. Fig. 204 is a section of a *flask* or *Atlas* trap, with vent, usually made of cast brass and depending upon two interior weirs to form the seal, one retaining the water, and the other dipping into the water to prevent sewer air from getting into the house through the fixture. If the water weir of such a trap becomes defective, there is no evidence except odors by which the occupants may discover it. If the dipping weir is defective the value of the water seal is *nil*. In either case the trap is no barrier to the admission of drain air to the house.

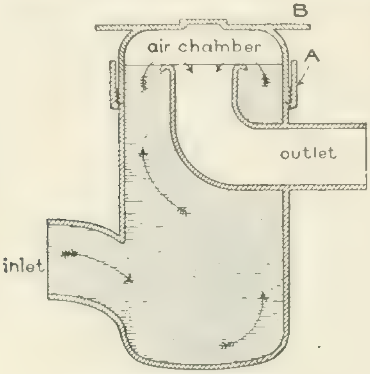


Fig. 205 Bath Trap with Submerged Inlet.

Fig. 205 illustrates a form of trap suitable for use with baths. It has a submerged inlet connection which is expanded so that the flow enters the trap at a dipping angle which produces a swirl with cleansing effect. The extension collar *A* is made so that the screw-cover *B* forms the gasket joint below the water-level. The method of providing the outlet in this trap makes it open to the same objection raised in connection with Fig. 203. This form, however, has the merit of being accessible for inspection without disturbing its service, which is impossible with the flask pattern shown in Fig. 204.

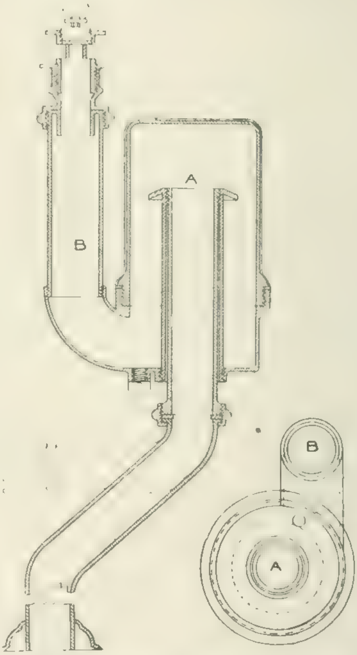


Fig. 206 Lavatory Trap with Interior Flanged Weir. Weir is Double-Walled to Betray Leakage.

The lavatory trap shown in Fig. 206, has an interior weir as shown at *A*; but the wall is doubled in such a way as to betray defectiveness by water leakage. It is made of cast metal, and is furnished with either glass or metal dome. The strong point claimed for this trap is the cleansing effect obtained by the flange extension of the exit, as shown at *A*, deflecting some of the water, which, together with the swirling effect produced by the tangential inlet, makes the trap self-cleansing.

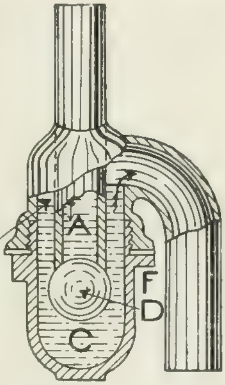


Fig. 207. Trap with Mechanical Seal Acting by Flotation.

Of the traps having a mechanical seal supplementing the water-lock, Fig. 207 is a specific type. The mechanical valve *D* is a rubber ball, lighter than an equal bulk of water, playing in the cup *C*. It acts by flotation, and presses up against the inlet *A* with a force equal to the difference in weight of the ball and the water it displaces. The body is generally made of lead; and the cup of glass, with screw-joint and gasket at *F*. This trap is proof against backwater; and, in case the waste line becomes choked below, will prevent a fixture from flooding even when others are discharged at a higher level. It has, however, several faults that counterbalance its merits. The inlet is open to the same criticisms that an interior wall of any other trap would be; the annular space at *R* accumulates filth; and the mechanical seal is worthless when most needed—that is, in the absence of the water-seal.

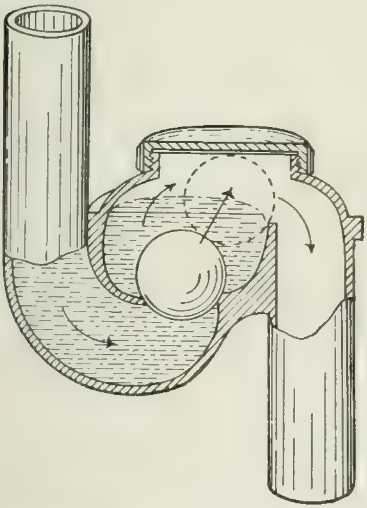


Fig. 208. Trap with Mechanical Seal Acting by Gravity.

Another mechanical seal trap, shown in Fig. 208, is the exact opposite of the previous example. The ball sinks by gravity, and effects a mechanical seal even when the water seal is absent. This trap is not so easily siphoned as a plain trap. It has a clean-out screw, and can be had with vent opening. Air from the sewer side acts against the clean-out cap through which access is had to the ball, and there are interior walls to become defective with little chance of discovery in practice.

A combined mechanical and water-seal trap is shown in Fig. 209, in which *D* is a hollow, flexible ball inclosing a metal ball D^1, thus giving a resilient seating surface that finds its place by gravity in water. The arrangement is proof against back-water, and the mechanical seal is positive without the aid of water. *A* represents the basin; *B*, the basin coupling; *C*, the valve seat; *F*, a glass cylinder body; and *GG*, a clamp with thumb-screw G^1, for clamping the cylinder body in place. This trap holds a large amount of water, and is not likely to become unsealed from lack of use, as part of the seal is protected by the ball, and should the water evaporate, the mechanical seal is still effective. There are no interior walls through which the trap could lose its seal without betraying the fact by leakage. Generally speaking, mechanical seals in fixture-traps cannot be depended upon.

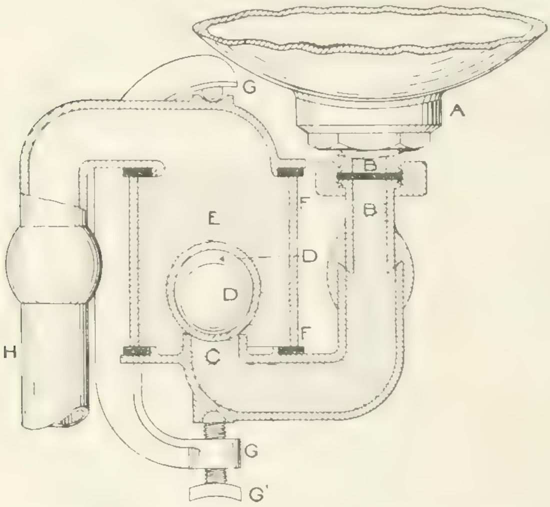


Fig. 209. Trap with Combined Water Seal and Gravity-Acting Mechanical Seal

Anti-siphoning traps are a blessing in instances where pipe ventilation is difficult. It would be better to have none of them, however, than to attempt to supplant pipe ventilation by their use to any great extent.

It would be impossible here to consider the whole list of traps individually in an adequate manner. What has been said should be enough to enable one by careful study to decide each case intelligently upon its merits. Many special traps are deserving of more favor than is generally shown them. It is the fear of seeming to indorse the horde of cheap competitive articles that causes many to ignore alike the good and bad. This fear is well grounded. The wolves will creep in if the door is opened at all.

Loss of Traps Seals. Traps may lose their seals in six ways—by *waving out*, by *capillary action*, by *leakage*, by *evaporation*, by *siphonage*, and—if the use of an unusual term be permissible—by *impellation*. The first, with its cause, has been described (see page 163). The last, like waving out, is caused by air-pressure, but on the house side instead of the sewer side of the trap. It occurs most frequently in intercepting traps where the fresh-air inlet has been connected too far from the trap, thus allowing heavy discharges of water and storm floods to compress the air between the fresh-air inlet and the trap. This action is of little consequence when so caused, as there is abundance of water to re-establish the seal. Its mention, however, suggests that a portion of the pipe is left unventilated by connecting the inlet too far from the trap. This error is usually made with good intention, because the foul-air outlet and fresh-air inlet are often made in the trap proper and are therefore too close together to pipe to the surface directly. There is a singular instance on record, of a trap having its seal broken by pressure on the house side—not from pressure of air in the pipe, but of that in the room into which the trap seal opened. This was a water-closet in a tight, unventilated compartment in a private house. Odors were often present which no one could account for. The job was new and first-class. The house was well built—too well. After many others had failed to diagnose the trouble, a plumber with some philosophy in his make-up examined the job. He stood in the hall, and slammed the closet-room door. It failed to latch, the room being so tight that the air-pressure kept it from seating on the rabbet of the frame. The door, of course, was instantly thrown partly open again by expansion of the air, and the plumber caught a glimpse of the water in the closet-bowl bobbing up and down. By repeating the experiment and measuring the depth of water between times, he discovered that, as suspected, the sudden closing of the door of the small, tight room was thrusting the water down in the bowl and causing enough to flow over into the soil pipe to break the seal. The trouble was remedied by cutting ½ inch off the door at the bottom.

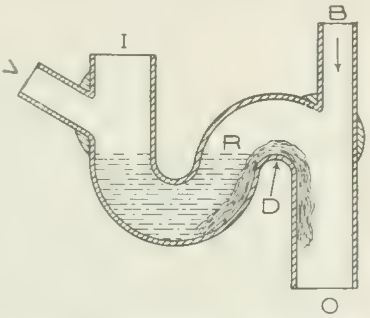


Fig. 210. Foreign Matter (Lint, Strings, etc.) Causing Capillary Loss of Trap Seal.

Evaporation has been described elsewhere. Leakage of seals has been mentioned in conjunction with types of fixture traps. Siphonage of traps is simple. The conditions necessary to start a common siphon being established in a waste pipe, the seal will be drawn out. The discharge of water from a fixture will siphon its trap (self-siphonage), if no provision against siphonage is made. The crown vent pipe, as described, breaks the siphon in a trap when its fixture is discharging, and prevents other fixtures from siphoning or waving out the seal. Capillary loss of seal occurs through hair, lint, and strings hanging over the weir of the trap. Dipping into the seal on one side, and ending in the pipe on the other, water will climb through or between such matter by capillary force, and will drip by gravity into the pipe. This is indicated by the tangled lines at *R*, Fig. 210, representing capillary material hanging over the outlet neck *D* of the trap. The trap indicated is for a lavatory with horn overflow bowl, *V* being the overflow connection, *I* the waste, *B* the crown vent, and *O* the outlet. Traps are sometimes locally vented at *V*.

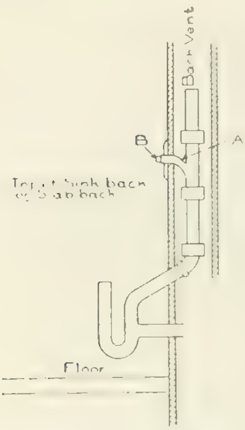


Fig. 211. Installation in which Provision is Made for Flushing and Cleaning Offset Vent Whenever Necessary.

Materials forming a porous coating on the inner walls of the trap through chemical action or otherwise, are now and then responsible for the loss of water-seal by action of a capillary nature. The shape of a trap may favor the accumulation of matter that will lead to capillary loss of seal. This is one reason why the plain, open-wall, cylindrical-bore traps are best. It is found that no matter how the trap is shaped, its surface is, as a rule, not used except at the points which conform to the simplest, most direct course—as before said. Other shapes, then, present needless fouling surface and space for accumulation of matter that interferes with the proper service of the trap. Departure from the shape mentioned is necessary to secure an unvented trap that cannot be siphoned. Any trap that must necessarily be connected so as to put the air of the sewer side against the gasket of the clean-out cap, should not be used.

A difficulty common to venting the general run of plumbing fixtures, is presented by the fact that to crown-vent the trap prohibits sufficient immediate vertical rise of the crown vent to get above the fixture overflow-level, without making an offset in the vent, which, in case of stoppage of the waste, favors choking of the vent in the offset by matter floated into it as a consequence of the stoppage. A plan providing for flushing of the vent at will, is shown in Fig. 211, a sanitary tee branch being placed in the vent above the level of the sink or lavatory back, as shown at *A*, and closed by nickel-plated trap-screw cover *B* at the face of the finished wall. In this way, by removing cover *B*, a wire can be run through to the trap-screw clean-out, and the offset portion thus cleaned; and, if necessary, it can be flushed by injecting water at *B* with a hose or funnel.

TOOLS USED IN PLUMBING

Some of the tools used in executing pipe work will now be briefly described. Of the lead-pipe tools, Fig. 212 is a *drift plug* or *pin* used for removing accidental dents from, and rounding up, lead waste pipe after it has been coiled for shipment. It can be used only when the pipe is detached and comparatively straight. The plug is greased, and is forced through with a piece of gas pipe with a cap on the driving end. These plugs are made in various lengths, for all sizes of pipe, generally with a slight taper. Boxwood is best for the purpose, but dogwood and even softer woods are used. Three to five plugs constitute a set for one size pipe; the smallest being at least $\frac{1}{4}$ inch less than the diameter of the pipe, so that, when the plug of the exact diameter has worn so that it is too small, one of the smaller plugs for the next size larger, used to begin the removal of the dents, may be employed instead. After a pipe is in place, there is scarcely any easy way to remove a dent, except by soldering a strong piece of strap solder to the lowest place and gradually pulling the dent out, keeping it warm with the torch so that the lead will give easily.

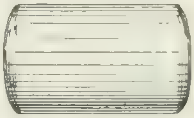


Fig. 212. Drift Plug or Pin

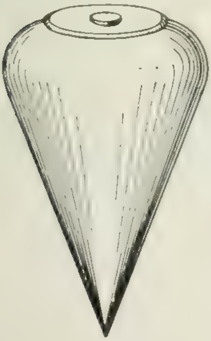


Fig. 213. Tampion or "Turn Pin."

Fig. 213 is a *tampion*—generally called *turn-pin* by plumbers, because it is turned after each stroke of the hammer, so as to insure swelling the end of the pipe uniformly. The turning is necessary because the pins become somewhat oval while seasoning. The heart of the wood is seldom in the center of the pin, and the shrinkage therefore is not equal toward the center. These pins are made of boxwood, with various tapers according to the work for which they are designed.

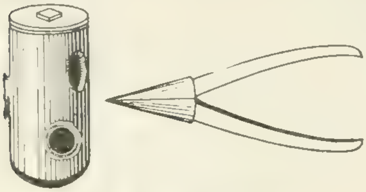


Fig. 214. Expanding Device for Enlarging Holes.

Fig. 214 is an expanding device for enlarging holes in drum-traps and for aiding in preparing the receiving end of the pipe, much in the same way as the turn-pin, before described, does.

Fig. 215 is a *tap-borer*. It is made for boring the openings in traps and waste pipes, and for reaming out the ends of supply when preparing for wipe-joints. Its work is seldom true, and the turn-pin is used for finishing. The plumber's rasp plays an important part in the preparation for joints, especially in preparing the spigot end.

Fig. 216 is a *bending iron*, used for straightening the ends of pipe and enlarging holes made by the tap-borer, generally performing in a satisfactory way the work described in connection with Fig. 214.

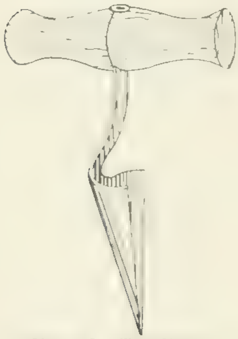


Fig. 215. Tap-Borer.

Fig. 216. Bending Iron.

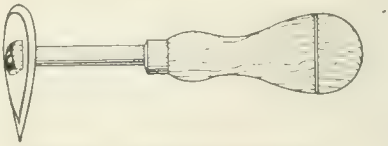


Fig. 217. Ordinary Shave-Hook.

Fig. 217 is a *shave-hook* of the type generally used on regular work. Lead tarnishes quickly; and in preparing joints, it is necessary to scrape clean the portion to which it is intended the solder shall adhere. The shave-hook is used for this purpose. To prevent reoxidation before use, joint cleanings must be immediately covered with tallow, lard, or sperm candle. The acid in sperm candle grease will cause solder to adhere where not intended, if one is not very careful.

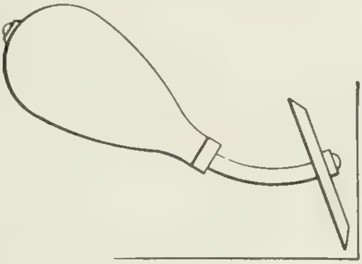


Fig. 218. Shave Hook with Bent Shank, for Use in Corners and Other Inconvenient Places.

On new lead, *soiling* is necessary, regardless of the kind of flux used. The whole end of the pipe or other surface about a joint is soiled usually to a distance of four inches for wiping purposes, before making the cleaning. Plumber's soil consists of glue and lampblack, a little glue being dissolved in water, and lamp black added to make the mixture about the consistency of cream or thicker, the whole being boiled to incorporate the glue thoroughly. Soil should be laid on hot, with a brush. The surface to which it is applied must be free of grease and dirt, or it will not stick.

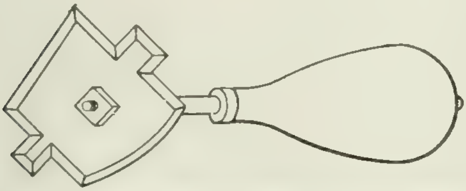


Fig. 219. Shave-Hook with Special Blade for Cleaning Seam Edges, etc.

Sheet lead is generally more or less greasy, no matter how clean and bright it looks, because tallow is used as a lubricator when rolling into sheets at the factory. New sheet lead should therefore be well rubbed with dry chalk, and dusted clean before soiling. Good soil should take a slight polish by rubbing with the hand after it is dried on the pipe. If it rubs off, there is not enough glue; if it cracks or peels or checks while drying, too much glue has been used.

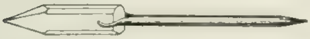


Fig. 220. Copper Bit or "Soldering Iron."

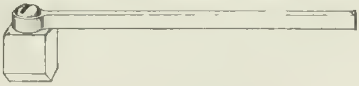


Fig. 221. Hatchet Iron.

Fig. 218 is a shave-hook with bent shank, convenient for cleaning in corners or other inconvenient places.

Fig. 219 is a shave-hook with special blade, with recessed edges of different lengths and depths, intended for cleaning tank-seam edges, etc.

Fig. 220 is a copper bit, generally called a *soldering iron.* It is of the same pattern as used by tinners.

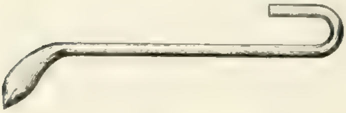


Fig. 222. Round Iron.

Fig. 221 is a *hatchet iron,* being distinctly a plumber's tool. It is adapted to soldering tacks on lead pipe and for making seams, also for other uses peculiar to the plumber's trade. It will revolve on the handle.

With the exception of Fig. 222, all soldering bolts used by plumbers are made of copper, because this material absorbs and parts with heat rapidly. For zinc work, steel bolts are used for soldering, as it is difficult to solder well on zinc with copper, because the copper parts with heat so readily as to easily melt the zinc. Fig. 222 is a plumber's *round iron*, made of iron. These are used in tank-seam work for keeping the mass of solder carried before the cloth in a semi-liquid condition. A number of these irons are kept hot in the furnace during the wiping of seams; and the helper brushes them clean, cools the handle, and hands them to the plumber, one at a time, as the iron in use becomes too cool to serve the purpose. It would be next to impossible to wipe a seam of much length without the aid of round irons, because it is impracticable to get up heat from end to end of the seam at one time. The entire contents of a pot is usually spit out with a stick or a ladle by the time one foot of seam has been wiped. The surplus is then massed and kept in working condition with round irons until the seam is finished or the surplus used, when another pot of solder is handled in the same way. When meeting a wiped seam, the end first wiped is covered with chalk, and the finishing end of the seam wiped up to it; and then, without unnecessarily disturbing or working over the solder on the chalked portion, the solder is massed over

Fig. 223. Wiping Cloth.

the junction of the seam, made thoroughly hot and workable at all points, and the seam wiped to a finish, the chalk preventing the melted solder above it from adhering to the solder beneath. If this is well done, there will be no evidence of the meeting place when the loose solder is removed and the chalk cleaned off.

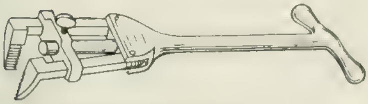


Fig. 224. Basin Wrench.

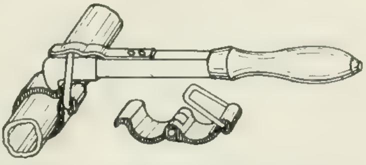


Fig. 225. Wrench for Polished Brass and Nickel-Plated Pipe.

Fig. 223 is a *wiping cloth.* These are made in various sizes—from 2 inches wide by 2½ inches long for wiping small flange joints, up to 5 by 6 inches for getting up the heat on large horizontal joints. They are of moleskin cloth or a good quality of bed-ticking. From 9 to 16 thicknesses of bed-ticking is required, according to the size of the cloth, to keep it from heating through so quickly as to annoy the plumber by overheating the fingers before the joint is finished. Some plumbers like one material best, and some the other, according to the contour of joint they are in the habit of wiping. The moleskin cloth is the stiffest and is generally preferred for round joints; but it is somewhat unwieldy for either supply or waste pipe branch joints. These, when wiped with a swell in the neck as well as on the side, are difficult to make with moleskin. Neither material wipes well when the cloth is new, because lint and loose fibers gather solder, which scratches the surface and mars the finishing wipe. To get rid of these, the cloth is singed, soiled, greased, and rubbed on a board to press the fibers down and pack the filling about them so as to keep them out of the way as much as possible until removed by usage. New cloths, until they are thoroughly broken in, are employed on ground work and other joints that will not be exposed to view.

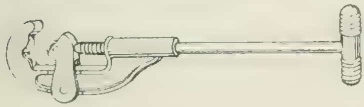


Fig. 226. Three-Wheel Pipe-Cutter.

Fig. 224 is a *basin wrench*, used for tightening and loosening basin-faucet couplings and lock-nuts, there being not enough room when the goods are in place to use wrenches of the ordinary kind.

Fig. 225 is a special wrench for screwing up polished brass and nickel-plated pipe, the finish of which would be marred by a common wrench. Friction swivels, with link, for each size of pipe, are furnished with the wrench. In use, the gripping power of the swivel is proportional to the pull on the handle, and the grip necessary to turn the pipe, as it becomes tighter and tighter when screwed up, is increased regularly, without attention, by the natural increase of force on the handle. There are several kinds of wrenches used for the same purpose. The one shown will do its utmost on the shortest piece of pipe it is possible to apply a wrench to.

Fig. 226 is a three-wheel *pipe-cutter*, with a hinged block carrying one wheel in a way that makes it possible to cut many sizes of pipe with one tool. Three-wheel cutters are handy to cut pipe off when in close quarters, as the work can be done without rotating the tool around the pipe, a travel of the cutter handle through an arc of about 120 degrees being sufficient to cover the entire circumference of the pipe with the wheels. Three-wheel cutters raise the burr on the outside of the pipe, which in a great measure obviates the necessity of reaming the ends to get the full nominal bore area, as the scrimp stock from which the ordinary merchant's pipe of to-day is made gives an actual interior diameter considerably more than the nominal, and the stock burred inward with a three-wheel cutter is just about equal in its reduction of the bore to the difference between the actual and nominal inside diameters. On full-weight pipe of proper outside diameter, the burr raised outside is very annoying to the fitter when new, close-fitting guides are in use, because it necessitates filing off the burr to some extent before the guide of the thread-cutting stock will slip over the end. On the other hand, with scrimp stock, where the outside diameter of the pipe is generally somewhat less than standard, the burr often constitutes the only portion of the thread that has a sharp top and bottom, which is necessary at some point in the thread to insure a tight joint. With worn dies and those of poor design, the outside burr acts in favor of starting the die without undue labor—a point of material advantage so far as labor is concerned when cutting threads on pipe of sizes smaller than those for which lead-screw die-stocks are furnished.

Other forms of pipe-cutters, with solid back and one wheel, or one wheel and two loose rollers, are made, the latter rolling the stock inward and making the burr so heavy that it should be reamed out in every instance. The wheel and roller cutters are used probably more than any other.

In connection with cutting iron pipe, some reference should be made to *pipe-threading dies*, of which there are many makes, not all worthy of use. It is generally admitted that careless and incompetent handling and the general abuse to which pipe dies are subjected by the general run of pipe fitters, are largely responsible for the poor work turned out and the generally discouraging service obtained from such tools. But with mild-steel pipe, which does not run at all uniform in hardness, and which is more unsatisfactory in every way to work than is the genuine wrought-iron pipe, it is necessary to employ good and well-designed dies in order to avoid extra labor and expense and to produce creditable results in thread-cutting. The rake and form of the die must be suitable to the kind of material to be cut; and it is economy to purchase modern dies designed with this point in view, and then to give them the same treatment that would be gladly accorded fine machinery of any other type.

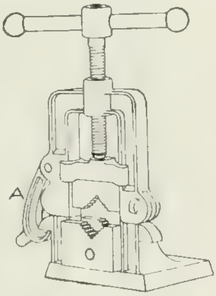


Fig. 227. Hinged Pipe-Vise.

Fig. 227 is a *hinged pipe-vise*. The upper jaw and frame are reversible so that the vise can be thrown open or closed to the right or left as required. The vise has a gravity pawl *A*, which drops into place automatically. A clutch at either side will engage the pawl when the vise is fastened to either the right or the left side of a post. A very desirable feature of the hinged vise is that pipe having fittings which will not pass through the frame at all can be quickly put in or taken out with no undue opening or closing of the screw, by simply lifting the pawl and swinging the vise back on the hinge.

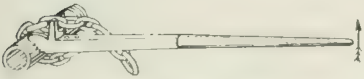


Fig. 228. Chain-Tongs.

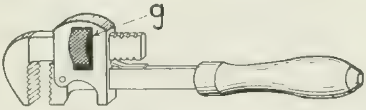


Fig. 229. Pipe Wrench for Small Work.

Fig. 228 represents a pair of old-fashioned chain-tongs, which may be used on any size of pipe the chain will reach around. There are other types, with double jaws, with chain hinged in center, which can be used either way, and which are more convenient.

Pipe wrenches are used for small sizes. Steel-handle wrenches are coming into use on large sizes. Fig. 229 shows a pipe wrench with wood handle, for small work. The jaw is opened or closed by rotating the knurled thumb-nut *g*.

Fig. 230 illustrates a plumber's *gasoline furnace*, adapted to heating solder pots and copper bolts. The gasoline supply for the blast passes through *AA*, and is provided with valve *H* and clean-out plug *I*. The lower end of the supply extends nearly to the bottom of the reservoir. The gasoline passes through coil *E*, which is partially filled with wire, usually a scrap of small wire cable, to prevent flame from running back into the reservoir, and issues from a single small hole at *F*, which is turned so that the flame will impinge on the coil. Air-pressure on top of the gasoline in the reservoir is necessary to make a blast. The air-cock is shown at *G*. For ordinary purposes, sufficient pressure can be obtained by blowing air in the hose at *C* with the lungs; but for a strong blast, a bulb containing check-valves, shown at *D*, is used to increase the pressure. The filling screw is at *B*.

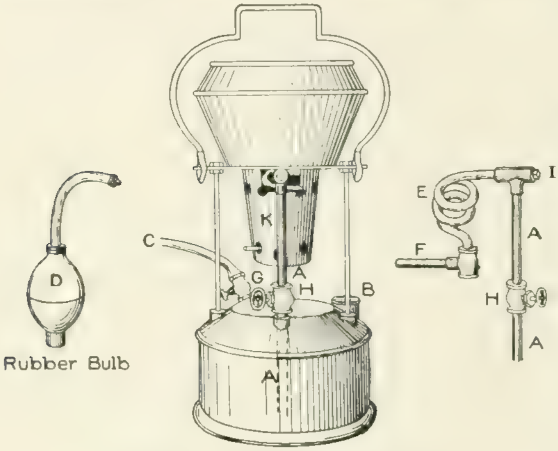


Fig. 230. Plumber's Gasoline Furnace.

To light the furnace, valve *H* is opened and some of the gasoline allowed to play on the coil, from which it falls back into the bottom of cup *K*. When about two tablespoonfuls have reached the cup, close *H*, and light the gasoline through one of the holes in *K*. When it has burned out, the coil will be hot enough to vaporize the gasoline as it passes through it; and a gas instead of a liquid then issues from *F* in the form of a blast, which increases in intensity as *E* becomes hotter. Any tendency to produce more gas than necessary merely increases the pressure and the force of the blast. The strength of the blast can be regulated by valve *H*. As the air is forced into the reservoir above the gasoline, one pumping keeps the furnace in working order until the lowering of the gasoline level has provided so much room that the pressure of the expanded air is not sufficient to maintain the blast. Then it becomes necessary to pump in more air, or to replenish the gasoline and again establish the pressure over it as described.

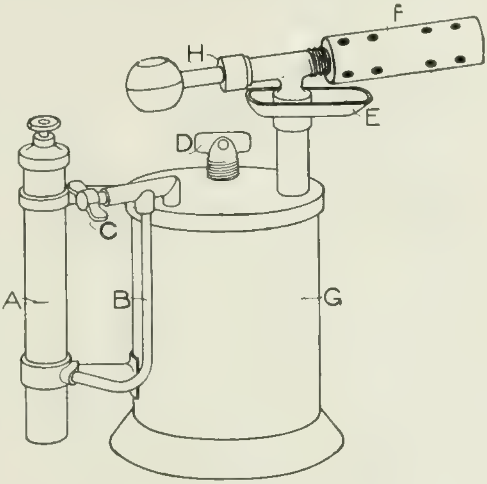


Fig. 231. Plumber's Blast Torch.

Fig. 231 is a *blast torch* used by plumbers for warming large joints, melting off old joints, heating soil-pipe hubs, thawing frozen water-pipe, etc. The principle of operation is the same as that of the furnace. *A* is a hand-pump for establishing the air-pressure; *B*, the air-pipe; and *C*, the air-cock connecting the pump to the top of the reservoir *G*. *D* is the filling screw, and *H* the supply valve to burner. The gas issues from a single orifice within the hood *F*. *E* is a gasoline cup used to heat the burner in order to start the blast, and corresponds to cup *K* of the furnace.

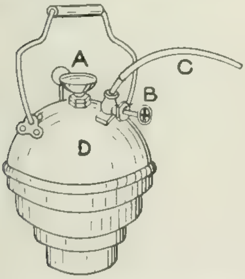


Fig. 232. Thawing Steamer.

The *thawing steamer*, Fig. 232, is made of heavy copper and adapted to fit the bowl of a plumber's blast furnace. *A* is the safety-valve, *D* the reservoir, and B the valve connecting with the steam space. For use, the reservoir is filled about three-quarters full of water, and heated to steaming point. The steam is conveyed through a hose *C*, and injected into the end of the frozen pipe. As the ice melts and the water flows out, the hose is pushed further and further into the pipe, until the ice is all melted out of the frozen portion. This is an admirable way to thaw water-pipe frozen underground, within partition walls, and in other inaccessible places.

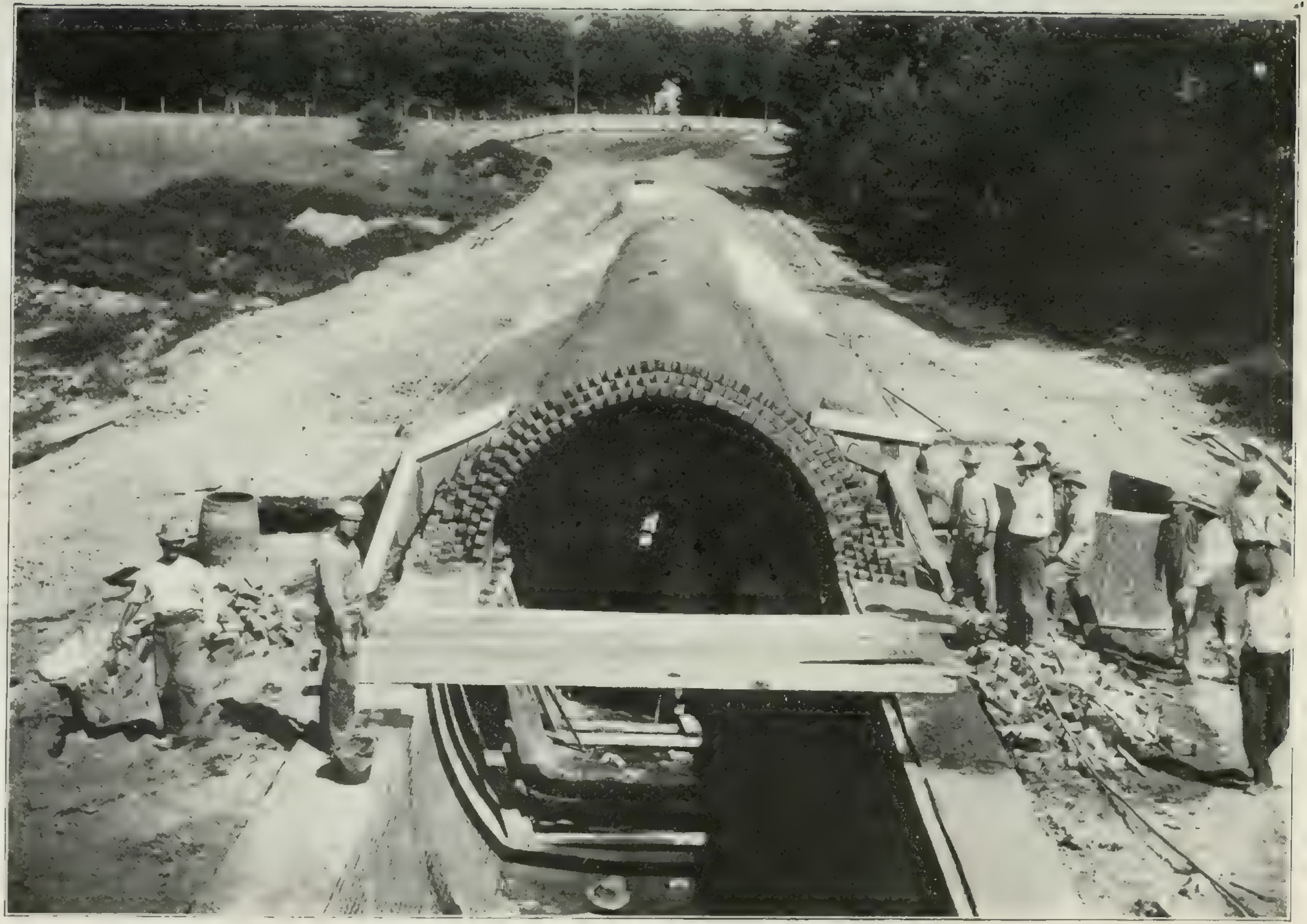
There are numerous other tools used by the trade, not only peculiar to the plumber's needs, but used also in common by workmen in other lines. All the data necessary concerning them can be had by reference to catalogues.

METHOD OF WIPING JOINTS

Watching somebody wipe joints, a clear description of how it is done, a thorough knowledge of the theoretical process, and acquaintance with the traits and qualities of the materials used, are essential; but practice in the art of wiping joints has more to do with making one proficient than has mere practice to do with proficiency in any other line of work. A Hottentot would succeed about as well in engrossing a set of resolutions, upon his first introduction to English and a pen and ink, as the most skilful person in other lines would in the work of wiping a joint at the first attempt. One may give the closest attention to the manual operations of making a thousand joints when the cloth and ladle are in the hands of someone else, and yet fail to remember the how and wherefore of a hundred movements absolutely necessary to success. Some general remarks are therefore all that will be of real benefit to any one previous to practice.

The same general result must be attained under a great variety of conditions, regardless of position or size or character of the pipe. The temperature and composition of the solder; the temperature of the weather; the kind, size, and position of the joint, etc., must be reckoned with in every instance, and each modifies the proceeding more or less at some stage.

Before commencing to wipe a joint, one should be positive that it is firmly set; that the cleaning is well done and of proper length; that the junction of the ends is well made, so that solder will not run through into the pipe; that the surrounding edges are well soiled, pasted, or otherwise protected, so that the solder will not adhere except at the cleaning; that the pipe is dry inside and outside; that no undue current of air is passing through it; that there is enough solder in the



SEWER IN FILLED EMBANKMENT, BOSTON, MASSACHUSETTS

Metropolitan Sewerage System.

pot to get up the heat and do the work; that the solder is hot enough; and that the cloth is in good condition.

To prepare for a joint, square the end of the pipe; see that the bore is true; rasp the spigot end evenly down to the bore, a little more obtuse to the outside surface than it is intended to make the boring or opening of the receiving end to that of the interior surface. Always rasp against the end of the pipe, so that no burr is made on the inside and so that none of the raspings get into the pipe. If the receiving end is to be opened with a turn-pin, the rasping on the spigot end should be made according to the taper of the turn-pin, and the end should be rasped down only partially, leaving stock enough to stretch when the end is expanded with the turn-pin. If the receiving end is to be opened with a tap-borer, then the spigot end must be rasped down in accordance with the angle of its boring. A coarse rasp will do to rough the work with; but one of fine teeth should be used to do the finishing so that the shave-hook will remove its marks. When the ends are thus prepared, soil them back three or four inches; and when dry, clean with a shave-hook, cutting rather deeply at the beginning of the cleaning so that there will be a slight thickness of solder at the edges of the joint; otherwise it would be impossible to wipe the edges clean and perfect, because the feather edge will chill too quickly. Before setting the joint, the tip edge of the spigot end and the bottom of the receiving end should be soiled, so that the two soiled parts will come together when the pipe is in place. This keeps solder from sweating through into the pipe.

The length of cleanings does not increase with the diameter of the pipe. The idea is to have the solder contact surface in proportion to the strength or purpose of the pipe. A round joint on $\frac{3}{4}$-inch pipe and one on 8-inch soil pipe should be about the same length—2 to $2\frac{1}{4}$ inches. On 4-inch soil pipe, the average width of a joint is about $1\frac{1}{2}$ inches. When the pipes to be joined are of different metals, it is best to increase the length of the joint somewhat, or extend the tinning. For instance, on copper pipe—especially for distillery use—some kind of galvanic or corrosive action takes place which destroys the union between the solder and the metal of the pipe. It is therefore usual, on distillery work, to tin across the end of the pipe and back on the interior, in addition to the regular joint surface outside, making the tinning continuous, as its length and continuity seem to determine the period of time the joint will last.

Difference in the ratios of expansion, causing a shearing action, appears to have much to do with the life of joints when lead and brass, lead and copper, or lead and iron are joined together by wiping. This is noticed more on water-back connections than elsewhere in the regular line of plumbing. When lead is joined to lead, the difference in the coefficients of expansion for the mass of solder and the metal of the pipe with which it is in contact, is so slight that little trouble is experienced in this way. The contour of the joint may be decided by allowing the thickness of solder at the middle to equal one and a-half times the thickness of the wall of the pipe. This holds good for supply pipe where the solder used is 40 to 45 per cent good tin and 55 to 60 per cent pure lead. On thin wall soil and waste pipe, or where coarser solder is used, twice the thickness of the wall is better. The solder forming the joint must be patted up compactly before wiping.

The beginner should keep the solder hot, leaving the pot in the furnace while practicing, so that he can put back and re-melt the cold batches from time to time, and continue to pour and re-wipe without loss of time. He can do no better than to try to imitate the motions of those who know how, whether he yet fully comprehends the reasons or not. Practice will soon teach him a few points which words cannot explain to the inexperienced. Lead and tin, not being of the same specific gravity, stratify more or less when melted, the tin rising to the top. For this reason, the molten mass should be skimmed and well stirred before dipping out any to wipe with. Never stir solder until ready to use it. Let the novice take the cloth in the left hand, holding it forward so as to cover the tips of the fingers, and take a ladle of solder in the right. Hold the cloth under the cleaning and drop the solder drop by drop upon the cleaning at different points, gauging the number, rapidity, and size of drops according to the heat of the solder. A single drop of solder too hot, may melt a hole through a thin wall pipe after it is pretty well warmed up. Keep the ladle moving so that the drops will fall in different places. When some solder gathers on the cloth, put it up on top again, and drop solder on it. When more runs down on the cloth, hold it against the bottom of the pipe to warm the bottom; and continue to drop solder from the ladle, more particularly now about the edges and even extending the pouring two inches or so out on the soiled part of the pipe on each edge, which will help to warm the pipe and provide heat in the pipe adjoining the edges of the joint to help keep the joint hot enough to wipe the edges clean before they chill.

Do little rubbing or passing on the edges. Let the solder stack up; dig some out of the top of the mass with the ladle to temper fresh solder from the pot, so that pouring a liberal stream instead of drops will do no damage. When the pipe has absorbed enough heat to allow the cold masses at the edges to be lifted easily, pass the mass around a little so as to tin the cleaning. Keep plenty of solder on the cleaning, and let the edges take care of themselves until the last.

When there is a good mass of solder on the cleaning, and the edges are thick and mushy, do extra pouring on the edges to get them thoroughly hot, and then place the solder on the cloth upon the pipe. If it is hot enough, the solder will tend to run off at either side again but it must be caught and pushed up. Then, with the aid of the thumb or an extra cloth in the right hand, push the solder around keeping plenty at the bottom, and get it patted up compactly into an egg shape with thick edges extending over on the soiled part, as quickly as possible. It may be necessary to pass or rotate the mass so as to get the cooler solder on the top to prevent it from dripping from the bottom. Experience will teach one how to mix the overheated portion with the balance so as to have the solder approximately at uniform temperature at all points by the time the joint is patted up.

The joint roughly shaped as described would hold water quite as well as after it is finished; but the appearance is bad.

Clean the edges first by pulling the cloth around, bearing down on one edge at a time. Then spread the middle and index fingers so as to let the cloth sag between them, and finish the joint by pulling the cloth around while bearing on both edges at the same time, keeping hold of the cloth by pinching it to the palm of the hand with the thumb. Beginners usually draw the cloth lengthwise of the joint to cut off the surplus carried around on the cloth by the finishing wipe; but an experienced person can finish the wiping while the solder is yet hot enough to sweat-in the cloth marks of the final wipe.

If the joint is wiped hot enough, and the heat evenly distributed, the tin spots on the surface when the joint is cold will be evenly distributed over the surface. If the pipe is hot enough, and the mass of solder too cold at any point, the friction of the cloth will cause the whole mass to rotate on the pipe. If too hot on the bottom, it will bleed the mass by dripping at the bottom. If too cold on top or at any other point, a very poor shape will result—if, indeed, one is able to wipe the joint at all. If the solder is fine, and a single wipe is made after the solder has fallen below the proper temperature, the surface will be covered with briar-like projections. If the solder contains any zinc, it will be brittle and work like cornmeal dough, and drip at the bottom when finished, if finished at all. All brass goods contain more or less zinc in alloy with copper, and it is best never to tin brass in wiping solder, as the zinc will melt out and ruin the solder.

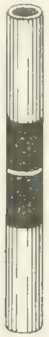


Fig 233 Butt Sweat Joint.

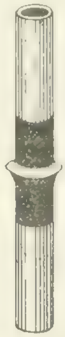


Fig 234. Blow Joint.

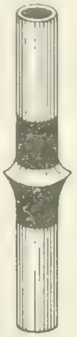


Fig 235 Copper-Bit Joint

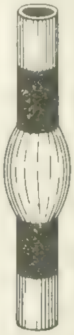


Fig 236 Round Wiped Joint on Small Pipe.

Many plumbers use two cloths when wiping. To become expert with the cloth, it is better to wipe all kinds of joints with one cloth only, until thoroughly proficient; then, if a second cloth is found to be of real service in some instances, use it.

A beginner may take every advantage to aid him—such as choking a pipe to keep cold air from passing through, heating brass or copper edges with a torch before wiping, placing a live charcoal on a piece of screen wire within the pipe to aid in heating up, wiping large joints in sections and meeting the edges by chalking the finished part as described in connection with tank seams, etc.—but he should never be guilty of making extra joints in order to shirk a difficult position. The quickest plan to master this branch of work, is to make joints in whatever position they happen to be required, instead of trying to arrange an easy way.

Wiped joints should be made wherever practicable; but there are several other styles of joints equally serviceable for certain locations. Fig. 233 is a *butt sweat-joint* made by squaring the ends, tinning one end, and sweating the other to it by heating with a torch. It is the weakest joint made, but will at the outset stand any strain or internal pressure that the pipe itself will stand.

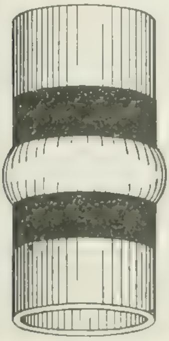


Fig. 237. Round Joint on Large Pipe.

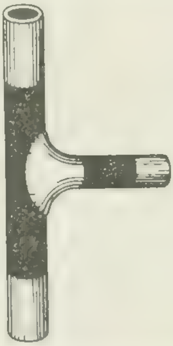


Fig. 238. Branch Joint with Concave Neck.

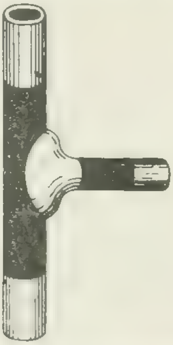


Fig. 239. Branch Joint with Swell Neck.

Fig. 234 is a *blow joint.* The only difference between it and the *copper-bit joint* shown in Fig. 235, is that the solder is floated by aid of the torch, and it is not so heavy as Fig. 235. The copper-bit joint is made with the soldering iron, the solder being melted and floated a little at a time until the joint is completed.

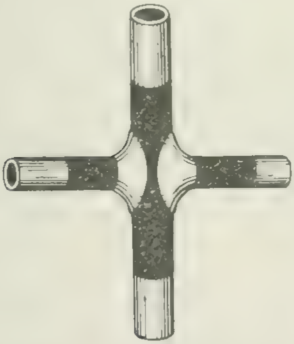


Fig. 240. Double-Branch Cross.

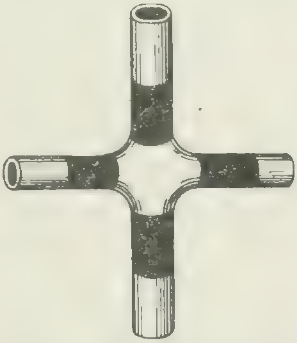


Fig. 241. Regular Cross-Joint.

Fig. 236 is a *round wiped joint* on ¾-inch supply pipe. For comparison a round joint on 5-inch soil-pipe is shown in Fig. 237.

Fig. 238 is a supply-pipe *branch joint with concave neck.*

Fig. 239 is a supply-pipe *branch with swell neck*, much more difficult to wipe than the style shown in Fig. 238.

Fig. 240 is a *double-branch cross.* This style of cross looks well, and is very easy to wipe, because one branch may be wiped at a time by protecting the first with chalk or paste.

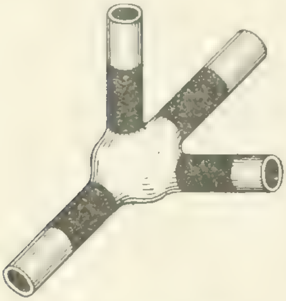


Fig. 242. Angle Cross

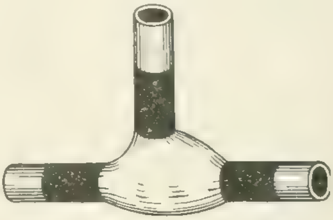


Fig. 243. Combination Branch and Round Joint

Fig. 241 is a *regular cross-joint,* more difficult than the double branch because there are four edges to take care of at one heat.

Fig. 242 is an *angle cross,* more difficult if anything than the wiping of Fig. 241.

Fig. 243 is a *combination branch and round joint,* sometimes made where it is most convenient to have a branch joint come at a point where two ends of the supply line must also be joined.

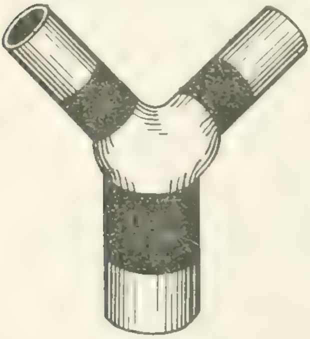


Fig. 244. Y Joint, Used Generally on Telephone Branch Cables.

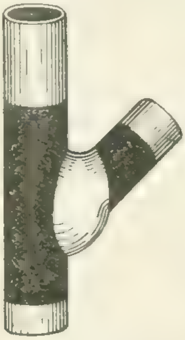


Fig. 245. Y-Joint on Lead Waste-Pipe.

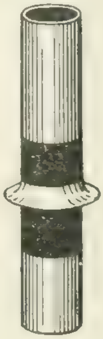


Fig. 246. Common Flange Joint.

Fig. 244 is a *Y-joint.* This form of Y is rarely wiped except for branch cables on telephone work. Many so-called Y-joints are made at a Y-angle on lead waste-pipe work, as shown in Fig. 245. As a general rule, none of these combination joints are made frequently enough of late years to keep a plumber in good practice. A common wiped *flange joint* is shown in Fig. 246.

An inclined joint can be set easily with two pairs of old dividers and two blocks to hold the pipe away from the wall. The table to catch what falls, should be a little toward the low side rather than centered under the cleaning. To wipe a joint in this position, pour well out on the soil, and let it stand without attempting to do much with the cloth. Temper the solder from the pot by digging out of the stack on the joint, and pour liberally. After the cold edges get melting hot next the cleaning, lift them into the pot. Then begin to pass the solder around with the cloth. Keep a good mass on the pipe. Pat up when hot enough, and cut the high edge clean first; then the top of the low edge. Then make some trial wipes, without pulling off any solder, to see if the joint is filled out to the proper contour all around. If not, use the surplus to fill the low places; then wipe down to the desired shape quickly. If the joint takes on any symptoms looking as if it had been stung by a bee on the low end at the bottom, cool it quickly with water.

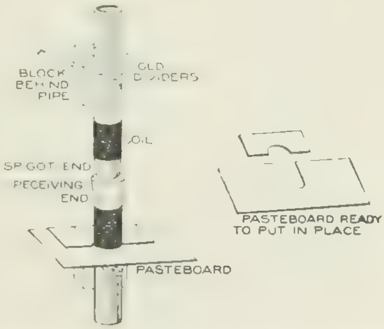


Fig. 247. Upright Cleaning Ready to Wipe.

To protect the wall on a flange joint over new wood wainscoting, such as is often made on sink wastes and vents, a large piece of pasteboard should be fitted over the pipe before the end is flanged. A blind flange joint requires a lead flange to be tacked to the wall over the pipe to support the joint. It is best to fit a lead flange the size of the joint in all cases, as less stretching of the pipe end is then necessary where the flange is also a union of two pieces of pipe. After the joint is finished, the pasteboard can be carefully cut around it and removed, leaving the wall clean. If the flange is to be made over marble, the pasteboard keeps the heat from running away from the edges, and there is less danger of cracking the marble by heat.

An *upright cleaning* is shown ready to wipe in Fig. 247. Plain upright joints are so easy, and occur so frequently, that the art of wiping them is soon mastered. The receiving end should be below and should be opened with the turn-pin and rasped off to suit. Its lower, inner edge and the tip of the spigot should be soiled. The ends should fit well, and the open part taper a little more than the spigot. The bulge helps to keep the solder up; and the cup, if well cleaned, will make a good joint alone. When wiping, either spit the solder on with a stick or pour on the cloth and drift it against the cleaning. Keep the mass up. Endeavor to pour solder on solder instead of on the cleaning. Leave the bottom edge alone until the cold fringe loosens of its own accord. When hot, form up roughly, high, and cut the top edge off clean first; then drag up the settling bottom edge, and fill out the low places; then wipe to finish, bearing the hardest on the upper edge of the cloth. The table can be made of two pieces of pasteboard as shown. Set it low enough to let the cloth and hand clear what drops when wiping. If cold solder surrounds the pipe when finished, melt it apart with the copper.

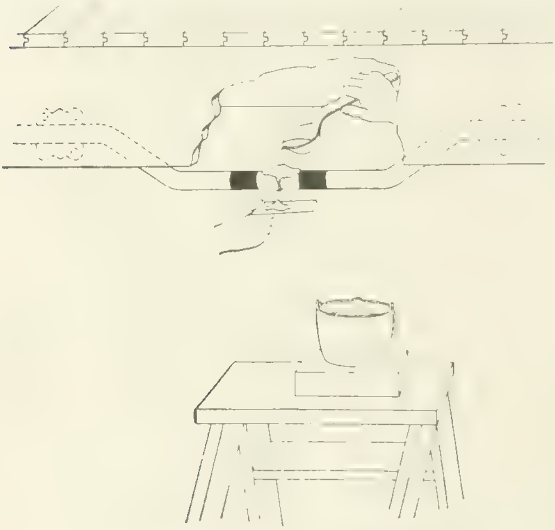


Fig. 248. Wiping an Overhead Joint.

The *overhead joint*, shown in Fig. 248, is wiped in the same way as though it were on the floor. The position is a trying one, and the cloth and ladle are kept in place at a great disadvantage. A stiff cloth is best to get the heat with; while a second, more flexible and previously warmed, can be used in conjunction, to do the shaping and wiping. Some heat previously applied with the torch to the edges, will shorten the time of getting the heat, and save the wrists and fingers from cramp and excessive tiring. Some provision for straightening the line is necessary, if a straight shoot is too high to wipe. Sometimes the surplus pipe is *snaked* into one plane with proper incline so that the pipe will drain, and is supported by a shelf.

THE MAKING OF CALKED JOINTS

In working cast-iron soil-pipe, frequent *cutting*, as it is termed, is necessary. To do this, all that is required is a hammer, and a cold chisel not too sharp. Make a line around the pipe as a guide, to insure making the piece the same length at all points. Then begin with hammer and chisel, pointing the chisel straight toward the center of the pipe and striking it quick, moderate blows, moving the chisel a little forward on the line after each blow, so as to make a continuous dent all around the pipe. Continue working in the dent until the pipe falls apart. The separating of soil pipe in this way is not a cutting process at all; it is simply packing the iron down in a line until the fiber of the iron is disturbed entirely through the wall, or at least sufficiently to wedge the pipe apart. Where the chisel strikes, the force tends to make the pipe longer, and the strain thus produced wedges it asunder.

Tools Used in Making Calked Joints. Fig. 249 is a *yarning tool*, the blade being long and thin in order to reach the bottom of the hub. The offset in the handle is to keep the hand out of the way of the pipe when using it. The *calking tool* is of the same pattern, with shorter blade and heavier. For calking and yarning joints standing close together or in a corner, special forms are needed. The *corner* tools, as they are called, are offset twice—once to keep the hand free of the pipe,

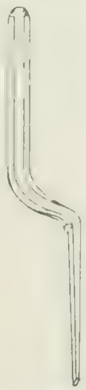


Fig. 249. Yarning Tool.

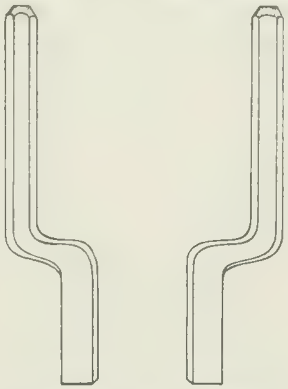


Fig. 250   Fig. 251.
Right and Left "Corner" Tools for Calking and Yarning.

and once edgewise, throwing the blade out of alignment both ways. The offset part next the blade is curved to the arc of the largest pipe it is to be used on, so that the blade will reach down in the hub vertically at the back of the joint, while the handle stands free in the open space for manipulation with the hand or hammer. These tools are necessarily made right and left, as shown in Figs. 250 and 251.

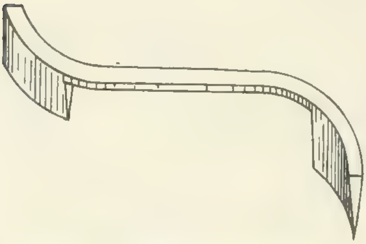


Fig. 252. Right and Left Calking Tool.

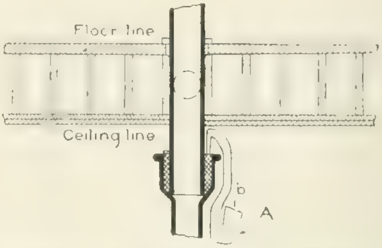


Fig. 253. Use of Special Tool in Calking Joint near Ceiling.

Another form of right and left calking tool is shown in Fig. 252, for use in finishing the joint as described in connection with Fig. 190.

Joints near the ceiling or in other positions, sometimes have to be made in places where regular tools cannot be used. The application of a special tool for the purpose is shown in Fig. 253, *b* being the hammer face, which is in position to use the hammer on quite conveniently. The hammer end *a* is made extra heavy, not only to prevent losing the force of the blow by vibration, but to give it weight in making effective jerking blows with the hand when pulling the yarn in.

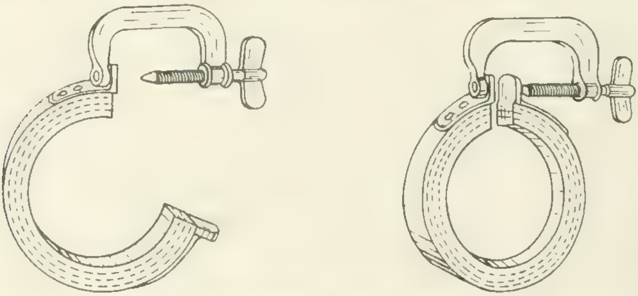


Fig. 254. Asbestos Joint-Runner, Open and Closed.

Fig. 254 illustrates a *joint-runner* made of square asbestos rope, with hinged clamp and thumb-screw attached for holding it in place.

There are other forms made that are just as good. These are used in running horizontal and oblique joints on cast-iron soil-pipe work. A fire-clay roll, formed about a strong cord by hand and used just damp and soft enough to bend and pinch in place, answers the purpose very well, though the weight of the lead, aided by steam bubbles formed from the water in the clay, sometimes blows them loose and imposes on the plumber the hard task of getting ready to re-run the joint, to say nothing of the time lost.

TESTING PLUMBING

Peppermint and ether are now but little used to test the tightness of soil and waste pipe. Better methods prevail. When the roughing-in work is finished, a *water test* is applied. The openings for fixtures and the outlet being closed, the whole system is filled with water, and no further progress permitted until it is water-tight. To avoid extra work in taking out defective pipe and fittings, cracked hubs, etc., it is best to fill the pipe as installed. Defects of material and workmanship are then brought to light at a time when they can be remedied at the least expense.

After the fixtures are set and connections made, a *smoke test* is applied to the completed job before it is passed for actual service. Devices for filling the pipe with smoke by burning rags or waste, are a part of every shop's equipment where city ordinances prescribe this kind of test. These are called *smoke machines*, and are moderate in cost and simple in operation. The smoke test is made under one to two inches' water-pressure, the pressure being shown by a water-gauge on the machine.

PLUMBING LAWS AND ORDINANCES

The municipal control of plumbing in the United States dates back only about twenty-five years, although some simple regulations were in effect in Lowell, Mass., and Providence, R. I., as early as 1878. The earliest codes with any claims to completeness took effect in 1881. The first such rules were made under the authority of general statutory provisions which conferred power on local governments to legislate on sanitary affairs. It soon became evident, however, that State legislation was necessary in order to give proper uniformity to the method of control; and general plumbing laws have now been enacted in more than twenty States.

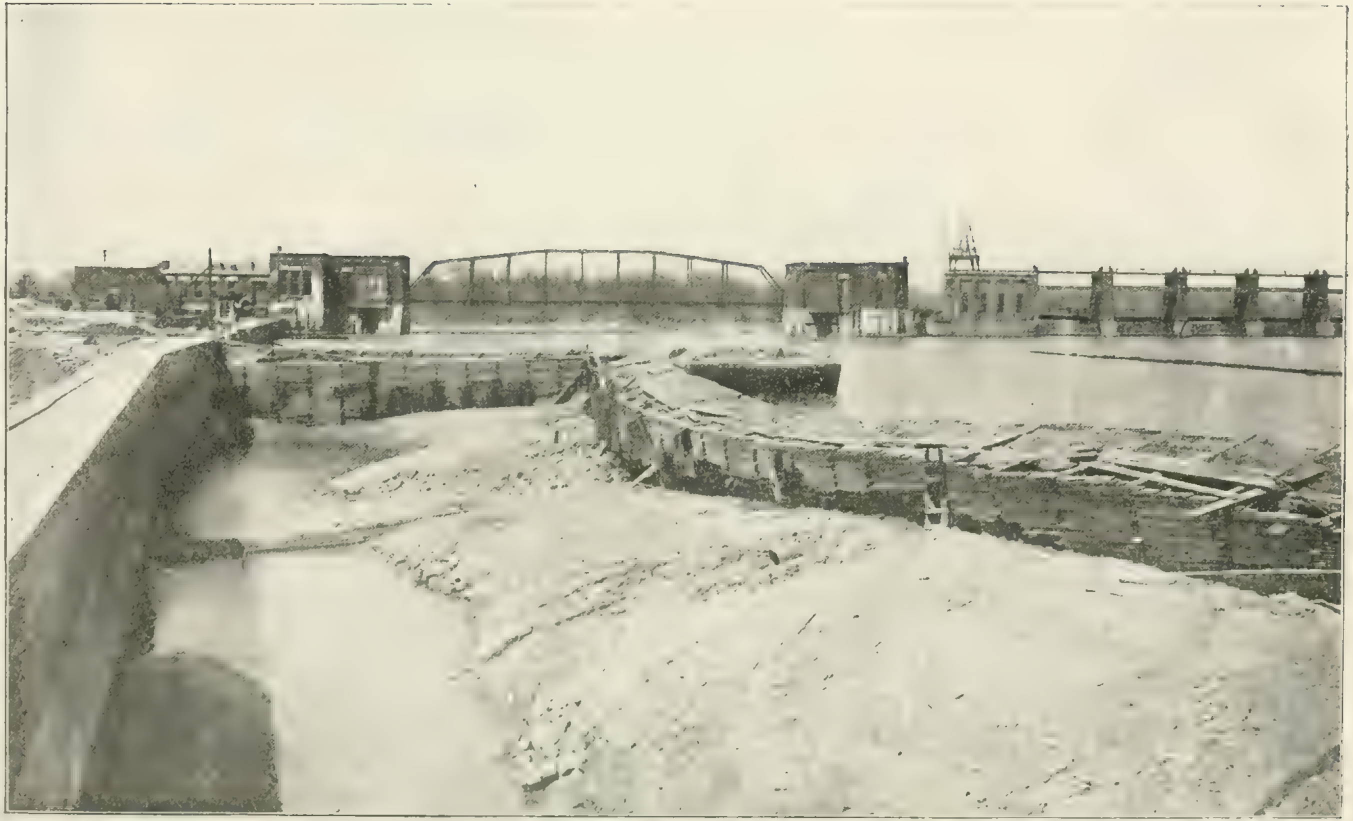
The application of the police power of the State—which may be broadly defined as "The power of promoting the public welfare by restraining and regulating the use of liberty and property" —was at first questioned when used in this connection. Owing, however, to the advances in public opinion regarding these questions of general welfare, it has been settled by numerous decisions that the regulation of plumbing construction by competent persons and in accordance with well-defined laws of design is a proper function of the Commonwealth. A recent authority has said: "The legislation on this subject has been the result of evolution, and conditions that were at one time tolerated are now recognized, with the growth of knowledge and the advance in sanitary science, as dangerous to life and health."

The scope of plumbing laws varies in the different States. They usually provide in general terms for the establishment of a Plumbing Board in each of the larger cities. Such a board generally includes at least one master and one journeyman plumber, together with some member of the Board of Health, or other city official, whose duties bring him closely in touch with plumbing construction. This board has authority to examine candidates for licenses as master plumbers and for journeymen's certificates, and to determine their competency to conduct the business or to work at the trade. If an applicant is not found competent, he is forbidden to do plumbing work. Either the board as above constituted, or the Board of Health, is charged with the duty of regulating plumbing design; and in most cities, ordinances have been framed with this end in view. The method by which plumbing shall be controlled is sometimes defined by the State law, and is in other cases determined by provisions of the city charter.

The extent to which regulations and ordinances prescribe the types of construction, varies greatly. In the smaller cities, a simple regulation comprising a few paragraphs is all that is found necessary. In the larger cities, long and complicated ordinances, with many provisions describing in great detail the materials to be used, the method of venting, etc., have been framed. The most notable of such ordinances is the comprehensive and consistent system of regulations prepared for the city of Cleveland, Ohio, but not yet (March, 1907) in force. This ordinance consists of sixteen titles, with numerous headings under each title, and is based on a very complete compilation of such regulations in force in the principal cities of this country. The great advances in plumbing design and in types of fixtures available create a necessity from time to time for some adaptation of plumbing rules to changed conditions; and, in general, it may be said that a set of regulations which has not received material modification within ten years past, does not prescribe the best methods of plumbing construction.

The jurisdiction under which the control of plumbing inspection should be placed whether with the Department of Health or with the Building Bureau has been a subject of some controversy. The enforcement of the earlier plumbing rules was entrusted to the sanitary authorities; and the supervision of plumbing is, in many of the larger cities, still in the hands of the Health Department. There has been, however, in the last few years, in connection with the more detailed study of features of plumbing design, a well-defined feeling that the questions of greatest importance fall within the province of the Sanitary Engineer, and may be logically treated by that department which has control of other details of building construction. In New York and Boston, as well as in some smaller cities, jurisdiction over the Plumbing Bureau is placed with the Department of Buildings.

Although the extension of plumbing supervision to those cities where it has not previously been in existence has been rapid, there still remain a number of large cities and many smaller ones which have neither regulations governing plumbing nor inspectors to supervise plumbing construction; and in many States no movement has yet been made to frame general laws upon this subject.



PART OF DAM CONSTRUCTION ON CHICAGO DRAINAGE CANAL AT LOCKPORT, ILL.

The temporary dam of stone, clay, and concrete here shown diverts water from the "Butterfly" dam and the new channel, to the "Bear Trap" dam and the Desplaines River.

SEWERS AND DRAINS

PART I

1. Introductory Definitions and Discussions. *Sanitary Engineering* is that branch of engineering which has to do with constructions affecting health. It thus might be claimed to include the manufacture and transportation of foods, the architecture of buildings, and many other things which affect the health of communities; but in ordinary use, a more restricted definition of the term is adopted.

In common practice, the term *Sanitary Engineering* is taken to include only *water supply engineering* and *sewerage engineering*, the former branch dealing with securing a satisfactory supply of water, and the latter with the satisfactory removal of surplus and waste liquids. Sewerage is the subject of this instruction paper, water supply being treated by itself.

Sometimes *sanitary engineering* is given a still more restricted meaning, and is taken to include sewerage only.

A *drain* is a canal, pipe, or other channel for the gradual removal of liquids. In sanitary engineering, the two principal kinds of drains are, first, those for the removal of comparatively pure ground waters and surface waters, as in land drainage; and, second, those for the removal of polluted liquids, as in sewerage systems.

A *sewer* is a drain for the removal of foul, waste liquids. Usually sewers are closed, underground conduits. An *open sewer* is an open channel which conveys foul, waste liquids.

Sewerage is a general term referring to the entire system of sewers, together with any accessories, such as pumping plants, purification works, etc. Thus we may speak of the "sewerage" of a city, or of the "system of sewerage," or of the "sewerage system."

Sewage is any foul, waste liquid.

Sanitary sewage is the foul wastes of human or animal origin from residences, stables, stores, public buildings, and other places of human or animal abode. By far the greater part (usually 99.8 per cent or more) of sanitary sewage, commonly, is ordinary water, which

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is added to the wastes themselves in this large volume simply to facilitate removal.

Manufacturing sewage is the foul wastes from factories. In different factories, it is of extremely different nature. It is often exceedingly strong, and very offensive and difficult to dispose of, as compared with sanitary sewage.

Storm sewage is the storm water flowing from city surfaces during and after rainstorms. Though polluted, especially at the beginning of a storm, from the droppings of animals and the other surface filth of cities, it is not so foul, nor so liable to swarm with disease germs, as is sanitary sewage.

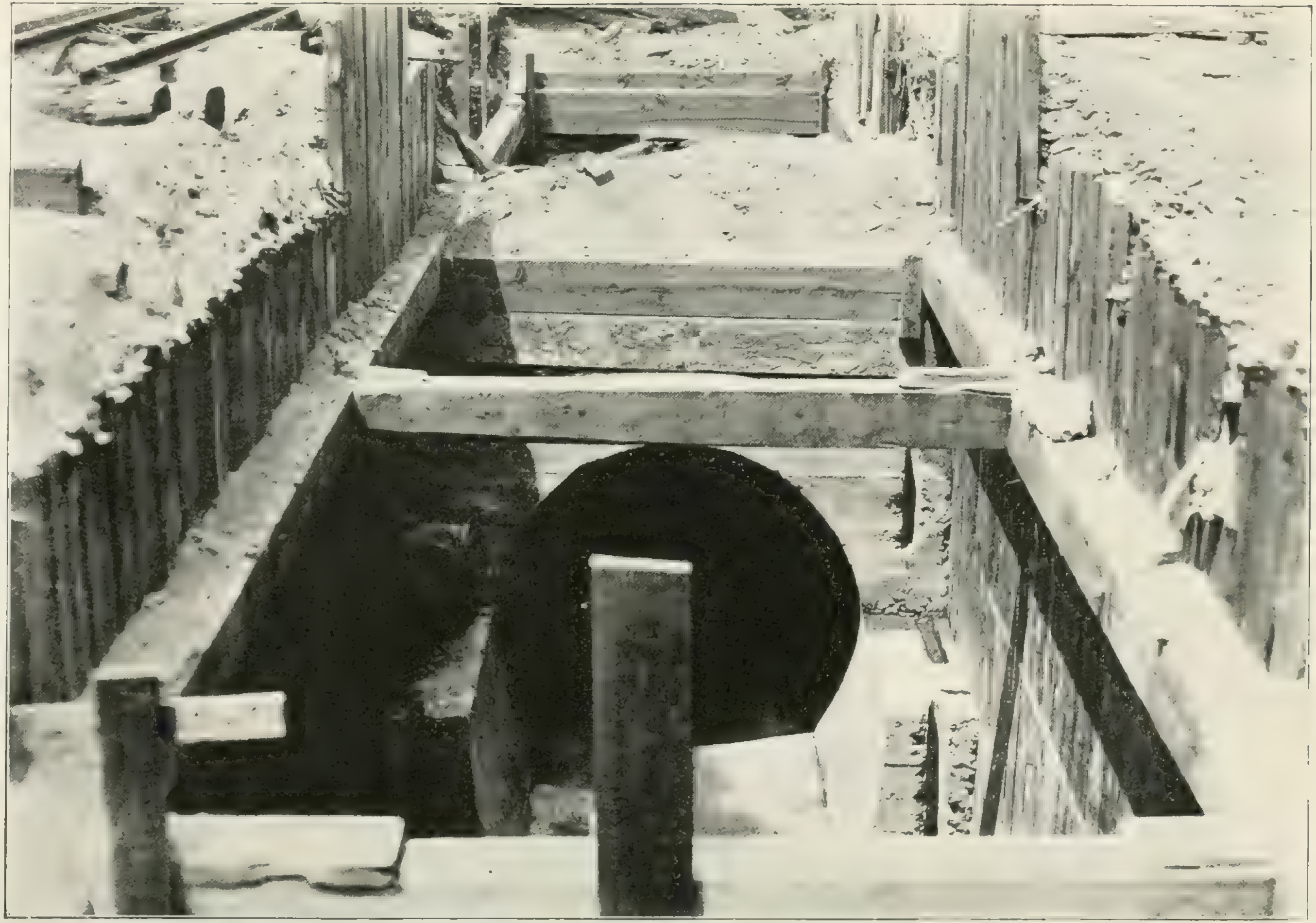
The terms *sewage* and *sewerage* are often misused by persons not engineers, to mean the same thing. Thus such persons often speak of the "sewage system" instead of the "sewerage system;" of the "disposal of the sewerage" instead of the "disposal of the sewage," of a city. So common is the misuse that some sanction can be found in the dictionaries; but engineers should be careful to restrict the meaning of the word "sewage" to the liquid which flows in the sewers, while the word "sewerage" should never be so applied.

Sewer air, often miscalled *sewer gas,* is the air in the sewers above the liquid contents. It has no definite chemical composition, but contains varying proportions of pure air and of carbonic acid gas, marsh gas, sulphuretted hydrogen, and the various products of decaying organic matter. Sewer air is constantly changing in composition even in the same sewer. While considered injurious to health when breathed, it has not been proved to be in itself the direct means of communicating infectious diseases.

2. Historical Review. Sewers and drains are of very early origin. Among the ruins of all ancient civilizations, are found the remains of masonry and tile conduits constructed for drainage purposes.

In Fig. 1, for example, from Fergusson's *History of Architecture*), are shown the remains of a large masonry sewer or drain built by the ancient Assyrians in the eighth or ninth century B. C., for one of their palaces at Nimrud. This is one of the earliest examples found of the use of the arch in masonry.

In Fig. 2 is shown the mouth of the *Cloaca Maxima,* or great sewer, of ancient Rome, built in the seventh century B. C., and still



SECTION OF CONCRETE SEWER PIPE IN TRENCH, BROOKLINE, MASSACHUSETTS

Metropolitan Sewerage System of Boston.

in use after the lapse of 2,500 years. Without this sewer, a large tract of ancient Rome could not have been inhabited; and in speaking of it, one authority says: "To this gigantic work, admired even in the time of the magnificent Roman Empire, is undoubtedly owing the preservation of the Eternal City, which it has secured from the swamping that has befallen its neighboring plains."

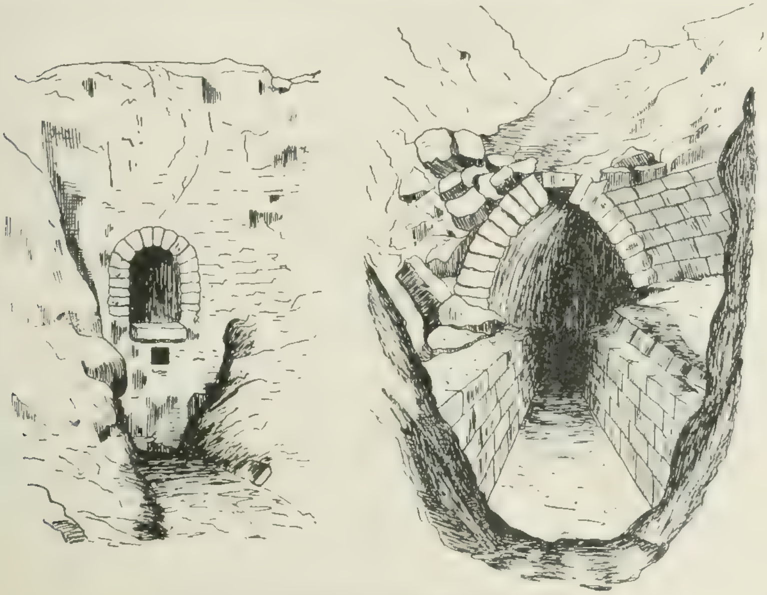


Fig. 1. Ancient Assyrian Sewers at Nimrud.

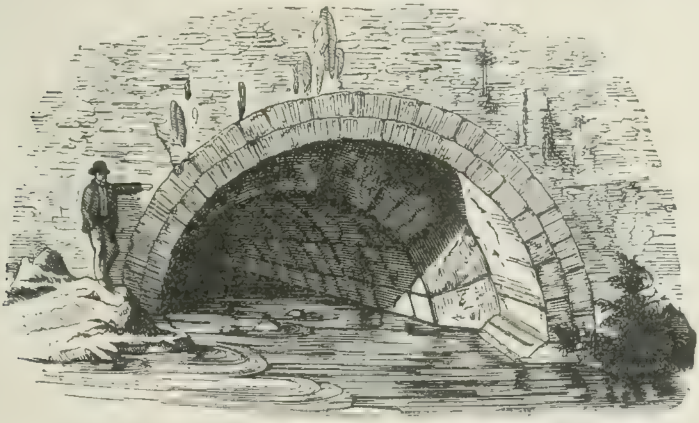


Fig. 2. Mouth of the *Cloaca Maxima*, or Great Sewer, of Ancient Rome.

In many other ancient cities and structures, the remains of intelligently planned drainage systems have been discovered; and it is evident that the ancients paid great attention to this matter so vitally affecting health. The art reached its highest ancient development in the time of the Roman Empire. The Romans, in fact, were the greatest engineers of antiquity, and especially excelled in sanitary engineering (both water supply and drainage). They were proficient in land drainage, as well as in sewerage.

With the fall of the Roman Empire, sanitary engineering suffered the same retrogression which befell learning and science; and for a thousand years—throughout the Middle or Dark Ages—it was almost entirely neglected. The impure water supplies and the accumulated filth of mediaeval cities produced fearful consequences in the terrible pestilences which desolated Europe.

With the revival of learning and science in the 14th and 15th centuries, attention again came to be paid to sanitary engineering; but for three or four hundred years more, little was done toward putting drainage and water supply on a scientific basis. Drains, rather than sewers, were built in the various towns as absolute necessity made imperative; but they were constructed piecemeal, and not so as to form comprehensive systems. They were not made watertight or self-cleaning; but it was usually considered necessary to make them large enough for men to enter to remove the filth, whose accumulation and festering in them were believed unavoidable.

In England, modern sanitary engineering may almost be said to have had its origin; yet so late as 1815, laws were enforced forbidding the emptying of fæcal matter into the sewers. "Such matter was generally allowed to accumulate in cesspools, either under the habitations of the people or in close proximity thereto."* In fact, though no longer enforced, these laws were not repealed until 1847, when Parliament passed an exactly contrary act, making it compulsory to pass fæcal and other similar foul matter into the sewers.

Modern sanitary engineering, especially as regards sewerage and drainage, has had almost its entire development since 1850. It was not until 1873 that there was published a comprehensive treatise on sewerage, that of Baldwin Latham, already quoted. At about this time, also, much attention began to be paid in England to sewage purification. It was reserved, however, for America to put sewage purification on the road to a satisfactory scientific solution, by the thorough investigations of the Massachusetts State Board of Health, begun in 1887 and still under way.

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*Baldwin Latham.

In America, much was done in the third quarter of the 19th century to advance sewerage engineering, through the studies of able engineers in connection with the design of systems for Chicago, Brooklyn, and other large American cities, the results being published in papers and reports, or in book form.

About 1880 the *separate* system of sewerage came strongly into prominence in America, as advocated by the late Col. Geo. E. Waring; and the construction of the Memphis (Tenn.) sewers on this system at that time, together with their great success in putting a stop to the fearful epidemics which had so often desolated that city, did much to make sewerage possible for small cities. At present, sewers have become so common and so necessary in modern life, that villages of 2,000 population, or sometimes of even less, are very generally taking up their construction.

With the present wide adoption of sewers, even by small communities, sewage disposal has come to be of very great importance, and is now undergoing great development. Many discoveries remain to be made in this line, in which the guiding principles have not yet been so thoroughly worked out as in the construction and maintenance of sewers themselves.

3. Importance and Value of Sewerage and Drainage. The importance and value of the constructions of sanitary engineering can hardly be exaggerated. Upon them absolutely depends the health of every city. One needs but to read descriptions of the great modern epidemics of yellow fever at Memphis and New Orleans, or of cholera at Hamburg, or to have been engaged to visit as sanitary engineer an American town during one of the numerous recent outbreaks of typhoid, to understand the truth of the scripture, "All that a man hath will he give for his life." Yet not only could sanitary engineering absolutely prevent every such epidemic; but, in addition, it could annually save thousands upon thousands of other lives which now succumb to bad sanitation.

Already very much has been accomplished in this direction by improved sanitation, though ideal conditions are yet seldom attained.

A prominent sanitary engineer estimated from actual statistics, that as early as 1885 there was a saving from this cause of 100,000 lives and 2,000,000 cases of sickness, annually, in Great Britain, in a total population of only 30,000,000. Figuring on the basis of the money value alone of the lives saved, and of the sickness and loss of time avoided, the money value of the above result would be almost incalculable.

In many individual cities, statistics have shown in death rates an immediate lowering, due to the construction of sanitary improvements, more than sufficient in money value to the community to pay for the entire cost. Funeral and sickness expenses saved, alone, often make enormous sums.

In this connection, it should be said that pure water supply and good sewerage are both essential, and that it is impossible to separate the value of one from that of the other. A polluted water supply may spread disease, no matter how perfect the sewerage, and an abundant water supply is essential to the proper working of sewers. On the other hand, without sewers and drains, an abundant water supply serves as a vehicle to enable unmentionable filth to saturate more deeply and more completely the soil under a city. Cesspools are even more dangerous than privy vaults.

In addition to direct prevention of communication of disease by unsanitary conditions, modern sewerage facilities are so great a *convenience* that this advantage alone is usually more than worth the cost. This is shown by the increased selling and rental value of premises supplied with sewerage facilities. No sooner is a partial or complete sewer system constructed in a town, than prospective buyers or renters begin to discriminate severely against property not supplied with modern sanitary conveniences; and persons looking for new locations for business ventures or residence purposes, discriminate in like manner in favor of towns having good sewerage.

So great has become the demand for sanitary conveniences, that they are now being installed in farmhouses as well as in the city. It is now possible for any farmer, at an expense of only a few hundred dollars, to have hot and cold water piped under pressure in his house, a bathroom and other plumbing fixtures, and his own sewage-disposal plant. This has already been accomplished in many cases. Such improvements, if made in accordance with correct principles, greatly better the sanitary conditions of the home; and they also prevent much disease by doing away with the exposure to inclement weather, which is so dangerous an accompaniment of the old-fashioned, barbarous, outdoor privy.

The great importance of sewerage may be realized by giving some consideration to the enormous sums of money which have already been spent for sewer systems in this country alone. Villages of 3,000 population in rural communities, often spend $50,000 or more upon a system. The city of Chicago has in recent years spent $50,000,000 in securing merely a satisfactory outlet for its sewers, without counting a dollar of the vast sums expended on the sewers themselves. In the United States, hundreds upon hundreds of millions of dollars have been invested in sewers.

SYSTEMS OF SEWERAGE

4. A *privy vault* is a receptacle, usually a mere excavation in the ground, for the reception of fæcal matter and urine. To prevent dangerous pollution of the surrounding soil and ground water, privy vaults should be lined with water-tight masonry; but this is seldom attempted, and even if attempted, is still more seldom accomplished, for it is difficult in such work to secure absolute freedom from leakage. The privy vault, frequently, is simply abandoned and covered over with earth when full, it being cheaper to change the location than to clean out the old pit.

The privy vault, with its inevitable befouling, in the immediate vicinity of the home, of earth, air, and water, the three great requisites of health, and with its danger from pneumonia and other diseases which may be contracted from exposure, should be adopted only in case of absolute impossibility to secure something better, and even then only as a temporary resort. It is not so objectionable in the country as in the city, if located far away from the well; but here the trouble is that it is usually placed too close to the well which furnishes the drinking water. In the country the leachings from hog pens, cattle yards, and manure piles frequently add to the contamination of the drinking water. It is impossible to set any safe distance at which a well may be placed from a privy, owing to the variable nature of the soil. The contamination may be carried very far in gravel strata or rock crevices. Impervious clay confines filtration within narrower limits.

5. A *cesspool* is a receptacle for receiving and storing liquid sewage. It consists usually of an excavation dug in the ground, lined with masonry, and covered, into which the sewer from the house discharges. To prevent contamination of the surrounding soil and ground water, the cesspool should be made absolutely water-tight, and its contents should be removed whenever it becomes full.

A *leaching cesspool* is one not made water-tight. The liquid contents partly leach away into the surrounding soil, and often into sand or gravel strata, or crevices in the rock, which may carry the contamination to great distances. Owing to the offensive nature of the work of cleaning out cesspools, and to the expense thereof, cesspools as a usual thing are deliberately made not water-tight. The owner congratulates himself if he strikes a crevice in the rock or a gravel stratum which prevents his cesspool from filling up, though even a little thought will often show that he is thus directly contaminating the water vein which supplies his own or his neighbor's well. Even then he does not usually escape permanently the expense and annoyance of being forced to clean out the cesspool, for in time almost any crevice or porous stratum will clog so as to permit only partial escape of sewage.

Leaching cesspools should be absolutely prohibited by law. They are even more dangerous than the privy, for the liquid sewage in them can penetrate further into the surrounding soil than the fæcal matter of the privy vault.

The frequent effect of cesspools and privies is illustrated in Fig. 3, which does not at all exaggerate conditions very frequently found in cities and villages. Often the tearing down of old buildings, prior to the erection of new, exposes to view the rear of lots, and shows sometimes a half-dozen privies grouped within a few rods of several wells. The nose and the eye give convincing evidence of foulness in such cases; and chemical or bacterial analyses are not necessary to demonstrate the danger in using the wells; but the same dangerous conditions pass unnoticed in many other places in the same city, because not exposed to casual view. In time, the whole ground water under such a village or city becomes contaminated, and poisons wells and damp cellars and the exhalations from the ground.

6. A *dry closet* is a privy having a tight, removable receptacle in place of the vault, and provided with means for covering the contents with dry dust, ashes, or lime each time the closet is used. Usually a small shovel and a box are used to hold the dust or other absorbent material. Enough of the dry material should be used to absorb all liquids. The contents should be removed and hauled away in the tight box when it is full, to be emptied in a safe place or used for fertilizer. The dry earth closet is an improvement over the privy vault, but is not a safe or otherwise satisfactory arrangement.

7. The *pail system* is one in which the fæcal matter and urine are received in tight pails, which are removed daily, or at least every few days, by regular city employees. The pails are carried to some safe place, there emptied, and returned after disinfection. Although the pail system has been tried in America under exceptional conditions, it is entirely unsuited for use here, and is almost never employed, even in Europe, where the people will submit to the police interference necessary for satisfactory operation.

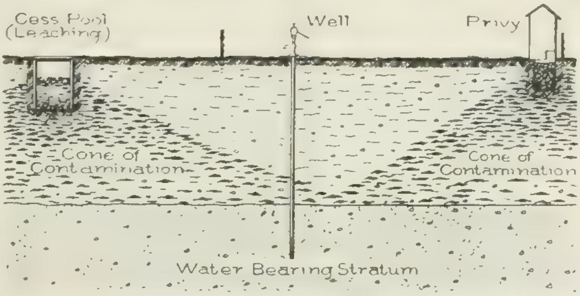


Fig. 3. Showing How Contamination of Well Water may Occur through Proximity of Cesspools and Other Sources of Filth.

8. *Pneumatic systems* of sewerage are those in which the sewage is forced through the street pipes by air, either by a partial vacuum, as in the *Liernur system* (tried in Holland), or by compressed air, as in the *Berlier system* (tried in France). Neither system is used at all in America, or to any important extent in Europe. The expense of construction and operation, and the liability of all such mechanical appliances frequently to get out of order, make them unworthy of consideration.

9. *Crematory systems* are devices for disposing of fæcal matter, urine, and garbage on the premises by drying and then burning. There are several patented methods. The matter to be disposed of is received in a furnace-like structure on the premises, built usually of masonry, which is open to a chimney, as well as to the various closets in the building. The chimney is supposed to maintain a current of air out of the rooms in which the closets are located; this dries the material, which is then burned at intervals.

Where sewers have not been available, crematory systems have been installed in many schools and other public buildings in the United States; but, while sometimes fairly satisfactory for a while, they are usually soon found to be troublesome, expensive, and dangerous. The air-currents sometimes reverse into instead of out of the rooms containing the closets; danger ensues unless the burning is regularly attended to; and, without constant care in the attendance, the whole apparatus is likely to get out of order. Moreover, it is entirely unadapted to the disposal of liquid wastes such as those from sinks, washbowls, laundry basins, and bathtubs, which are as necessary to be taken care of as fæcal matter and urine.

In the foregoing paragraphs (Arts. 4 to 9), various makeshifts for caring for sewage have been described which are not worthy the name of "systems," although the privy vault and the cesspool are in very wide use. We next come to the only methods for removing sewage which are at present worthy of serious consideration when planning a sewerage system.

10. Water-Carriage Systems. Water-carriage systems of sewerage are those in which water is added to the fæcal matter and other foul wastes in such quantities as to permit of their rapid removal by gravity in sewers. As already stated, the water so added usually constitutes 99.8 per cent or more of the resulting sewage.

Water-carriage systems are now so universally used for sewerage purposes, that usually the two terms may be considered synonymous. That is, in the present day, a sewerage system is practically always a water-carriage system.

There are two kinds of water-carriage systems—namely, the *Combined System* and the *Separate System.*

11. Combined System. The combined system of sewerage is that in which the storm sewage flows in the same sewers with the sanitary and the manufacturing sewage. The combined system came into use prior to the separate.

12. Separate System. The separate system of sewerage is that in which separate sewers are provided for the storm sewage and for the sanitary and manufacturing sewage.

13. Comparative Merits of Combined and Separate Systems. The separate system came into prominence about 1880. At that time and for many years following, there was an active discussion over the relative merits of the two systems, some prominent engineers advocating one, and some the other. At the present time, the discussion has died down, and sanitary engineers use both, adopting whichever is best suited to local conditions, and often using a combination of the two.

In favor of the separate system, the following points have been cited:

1. The sanitary sewage which constitutes the dry-weather flow of combined sewers is so very small in comparison with the storm sewage, that in circular sewers, which are the most economical to build, it forms merely a trickling stream, with little velocity, over the bottom of the large sewers required; while in the separate system the sewers are proportioned for this small volume, and the sewage consequently has good depth and velocity. Moreover, sanitary sewers are free from the sand and other street detritus which are inevitably washed into combined sewers during storms, and which are especially troublesome in forming deposits. Hence, in the separate system, it is easier to make sewers self-cleansing from deposits.

2. Above the low-water line in combined sewers, the extensive interior surfaces of the large sewers required become smeared with filth in times of flood, which remains to decay and produce foul gases after the flood subsides.

3. On account of the comparatively small size of the sanitary sewers of the separate system, it is easier to flush them so as to keep them clean. Automatic flush-tanks can be used at small expense to do this very satisfactorily.

4. On account of the comparatively small size of the sanitary sewers of the separate system, the air in them is much more frequently and completely changed by the daily fluctuations in the depth of sewage and by the currents of air through ordinary ventilation openings. Hence, in the separate system, ventilation is easier and more perfect.

5. In case the sewage has to be purified, the separate system is more economical, because only the sanitary sewage need be treated, the storm sewage being discharged into nearby natural watercourses.

6. In small cities, and in large portions of large cities, the storm water can usually be carried some distance in the gutters, and then removed by comparatively short lengths of storm sewers, laid at shallow depths and discharging into the nearest suitable natural watercourses. In such cases, a separate system of sewers will usually cost only a fraction, frequently only one-third, as much as a combined system. For small towns, the great cost of a combined system would often prohibit the construction of sewers entirely, or postpone it almost indefinitely, were it not that a separate system can be built so cheaply. On this account alone, the introduction of the separate system of sewers has been of incalculable benefit in America.

7. On account of their relatively small size, sewers of the separate system can be made almost entirely of vitrified sewer-pipe, which has the important advantages over brick sewers, of greater smoothness, of being impervious, of having few joints, and of ease in making the joints practically water-tight. It is impossible to make even a pipe sewer absolutely water-tight, and with brick sewers the difficulty is very much greater.

In favor of the combined system, the following allegations, corresponding to the above points, have been made:

1. By making combined sewers egg-shaped with the small end down, or by making a small, semicircular channel in the bottom (see Figs. 19, 24, and 25), the depth and velocity of the dry-weather flow can be made sufficient to cause the sewer to be self-cleansing.

2. The coating on the interior surface of large sewers above the low-water line is not dangerous, and in fact is of very little importance.

3. While it is true that the smaller, separate sewers can be flushed more perfectly for the same expense, the larger, combined sewers are more convenient for removing obstructions, and are flushed out very completely (though at too long intervals in dry weather) by the floods of storm sewage during rains.

4. In regard to ventilation, the larger volume of air over the sewage in the larger, combined sewers dilutes to a much greater degree the gases from the sewage.

5. In case the sewage must be purified, it must be remembered that the early flow of storm sewage from the streets is foul, to some extent, from the droppings of animals and other surface filth; and it may in some cases be questionable whether this may not require purification in addition to the sanitary sewage.

6. Wherever, as in the case of the business districts of large cities, it is necessary to provide as great a length of storm sewers as of sanitary sewers, it will be cheaper to build one set of sewers, as in the combined system, rather than two, as would be required in such districts with the separate system.

The *general conclusions of sanitary engineers* at present regarding the relative merits of the separate and combined systems, are as follows:

a. Either system can be made satisfactory from a sanitary point of view.

b. The cost of a properly designed system, including means for safe disposal of sewage, should ordinarily decide which of the two systems should be built.

c. On the basis of cost, the separate system is usually the better for small cities, for suburban and sometimes residence districts of large cities, and for all cases, even those of large cities, where the sanitary sewage requires treatment while the storm sewage can be safely discharged into nearby watercourses. The separate system has just been recommended for the city of Baltimore on this last account.

d. Similarly, on the basis of cost, the combined system is usually the best for the business and other very thickly built-up districts of large cities, and, in general, where storm sewers must be coextensive with sanitary sewers; also for cases where both storm sewage and sanitary sewage require purification.

e. Often a combination of the two systems can be made to advantage, storm water being admitted to the sewers only in certain portions of the system, such as the business districts.

GENERAL FEATURES OF SEWERS

14. Kinds of Sewers. *Sanitary sewers* are those constructed to carry foul waste liquids of human or animal origin—that is, sanitary sewage. Since sewage of human or animal origin is most apt to contain the germs of human diseases, sanitary sewers require special precautions in design, construction, and maintenance, to render them safe. Manufacturing sewage is often, however, even stronger and more offensive than sanitary sewage, and hence requires equal precautions. In the separate system, the manufacturing sewage should go into the sanitary sewers or into special sewers of similar character.

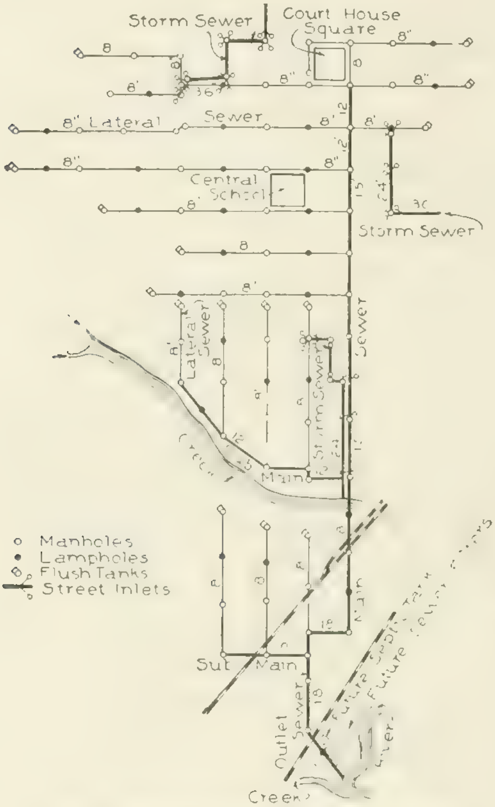


Fig. 4. Kinds of Sewers and Arrangement of Accessories.

Combined sewers are those constructed to carry both sanitary sewage and storm sewage. With the combined system, the manufacturing sewage also usually goes into the combined sewers.

Storm sewers are those constructed to carry storm sewage only.

An *outlet sewer* is one connecting a sewer system, or a part thereof, with the point of final discharge of the sewage.

A *main sewer*, or *sewer main*, is the principal sewer of a city, or of a large district thereof, into which branch sewers discharge.

A *sub-main sewer* is a branch of a main sewer, receiving in its turn the discharge of smaller branches.

A *lateral sewer* is one not receiving the discharge of other sewers, hence serving only property closely adjacent.

In Fig. 4, the various kinds of sewers above described are shown, from a portion of the actual sewerage map of a small city, sewered on the separate system.

15. *Intercepting sewers* are those built across lines of other sewers, to intercept the sewage flowing in them and carry it away to different outlets.

In Fig. 5 are shown the intercepting sewers of the city of Chicago, built along the lake front to intercept the sewage in the sewers which formerly discharged into and polluted Lake Michigan, from which the water supply of the city is taken. From the intercepting sewers, the sewage is pumped into the Chicago River, which now discharges through the great Drainage Canal into the Desplaines river, the Illinois River, the Mississippi River, and the Gulf of Mexico.

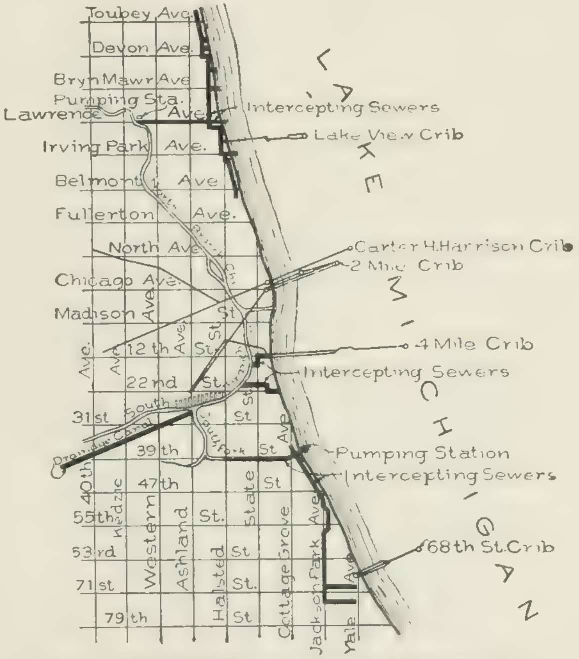


Fig. 5. Intercepting Sewers of the City of Chicago, Ill.

16. General Description of Sewers. Sewers, as usually built, are smooth pipe or masonry conduits, as nearly water-tight as practicable, buried in the ground as deeply as necessary to serve the adjacent houses and drain other territory tributary upstream. They are very carefully constructed to an exact grade line, determined by the engineer who made the sewer plans.

Unless special circumstances require other forms, sewers are usually made circular, this shape giving the greatest strength and area for a given amount of material. For other shapes, and the circumstances to which they are adapted, see Figs. 19 to 25.

The *invert* of a sewer is the lowest point on the interior surface (being so called because the interior curve is there inverted). When the grade of a sewer is mentioned, or the elevation of the sewer at a given place is spoken of, the invert is always meant. The invert is also sometimes called the *flow line.*

Almost all sewers up to 24 inches' diameter, and many from 24 to 36 inches' diameter, are made of vitrified or cement pipe. Above these sizes, concrete or brick masonry is ordinarily used. Stone masonry and iron pipe are also used, but only seldom. A comparison of these materials is given elsewhere in this paper.

At intervals along sewers, *manholes* (Art. 21) and *lampholes* (Art. 22) are placed to permit examination and repairs, and often *flush-tanks* (Art. 23) are provided to keep the sewers clean. In the case of storm sewers and combined sewers, either *street inlets* or *catch-basins* (Art. 27) must be provided, for admitting the storm water to the sewers. These are usually placed at or near the curb corners at the street intersections.

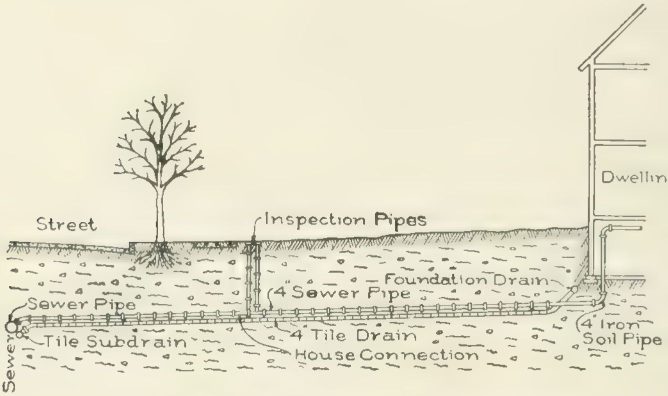


Fig. 6. Street Sewer, Subdrain, and House Connection.

A general idea of the relation of a sewer to a building served by it, may be gained from Fig. 6. The sewer there shown is a pipe sewer. Usually all lateral sewers are made of pipe; and in the separate system, the submains and mains also, unless the city is quite large.

17. Location of Sewers. Sanitary sewers are usually placed on the center lines of the streets, so as to give equal fall from the houses on both sides. On this account, water, gas, and heating mains, storm sewers, and other conduits should be constructed far enough from the center lines not to interfere with the sanitary sewers. Not infrequently the center of the street is found already occupied by other conduits which were located without proper foresight; and it is then necessary to place the sewer nearer to one side than the other.

In cases of streets on side hills, it is sometimes necessary to place the sewer close to the downhill side of the street, in order to serve houses on that side which are lower than the street grades.

In a few cases of excessively wide avenues, especially if paved, it is cheaper to build two lines of sanitary sewers, one on each side, than to construct the longer house connections required.

In any town having a fairly extensive system of alleys, careful consideration should be given by the sewerage engineer to the feasibility and desirability of locating part or all of the sanitary sewers in them instead of in the street. In Memphis, this plan was followed as far as practicable. It is not usually feasible to locate combined or storm sewers in alleys, because such sewers must receive storm water from the streets running in both directions, and hence must usually have the street inlets placed at the street corners.

Streets vs. Alleys for Sanitary Sewers. Location of the sanitary sewers in the alleys has a great advantage in avoiding the tearing up of the streets and pavements for sewer repairs and for new house connections, which not infrequently causes them serious injury. Pavements are often ruined by the trenches dug for water, sewer, gas, and other connections. Also, if the sewers are in the alleys, the trenches for house connections do not cross the lawns in front of the houses.

On the other hand, the system of alleys in the ordinary town is a public nuisance. They are usually filled mainly with manure piles, garbage, and debris of all descriptions; and they open through the middle of the blocks vistas which suggest most forcibly a neglected city dumping ground. Owing to their vile sanitary condition, the alleys are usually the first danger spots demanding attention when a town is threatened with an epidemic. Except in the business districts where they can be paved and policed, there is no necessity for alleys unless the lots are very narrow, for in almost every town there are sections which do without and never miss them. Teams can without inconvenience drive in from the front, along a cinder or gravel drive. Such sections are better off without the alleys, from both the sanitary and the æsthetic points of view.

For the above reasons, it is often unwise to perpetuate, or perhaps even extend, the alley system by locating sewers in them.

Again, the system of alleys, more often than not, is far from being as complete as the street system; and in such cases it will usually add considerably to the total length of sewers required to serve a given territory, if part of them are placed in the alleys. The alleys, also, are usually too narrow to permit the construction of sewers of considerable depth, without trouble as regards the excavated material, the handling of pipe, etc. Moreover, houses and the fixtures in them are usually so located that the house connection would be longer to the alley than to the street, requiring a deeper sewer for equal service. This, however, is not always the case.

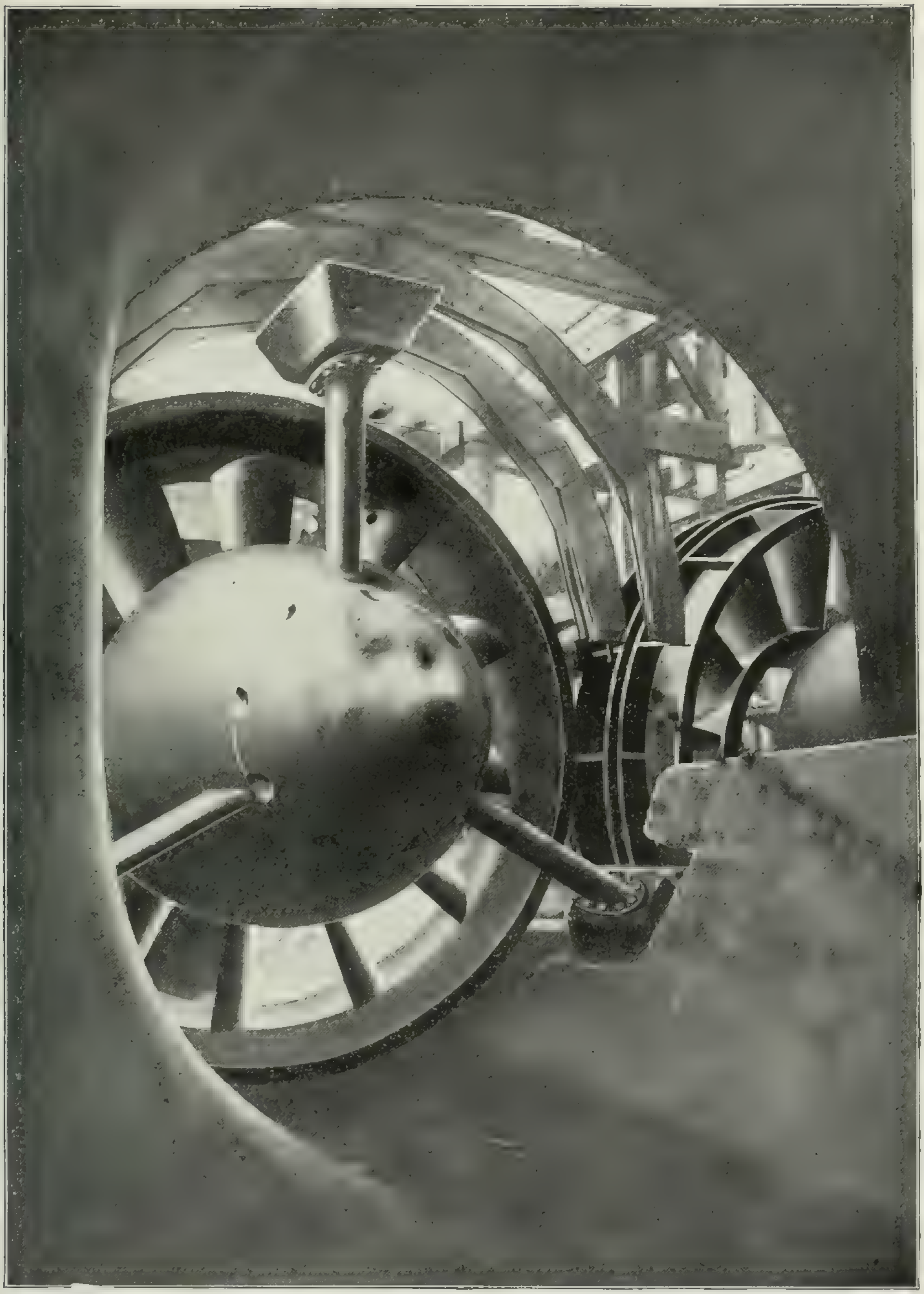
The sanitary engineer should study each town by itself, and decide this question after giving due weight to all these various considerations.

18. Depth of Sewers: The depth of sanitary and combined sewers should be great enough to afford good drainage to the basements of all buildings. This will usually call for the tops of the sewers to be about 3½ feet below the basement floors, as follows:

MINIMUM DEPTHS FOR SANITARY AND COMBINED SEWERS

Fall from sewer to house	2 ft. 0 in.
Fall from basement floor to house connection	1 ft. 6 in.
Total from *top* of sewer to basement floor	3 ft. 6 in.
For *sewer laterals,* add to the above for fall at sewer	1 ft. 0 in.
Total from *invert of lateral sewer* to basement floor	4 ft. 6 in.
For *residence districts,* add for ordinary-depth basements below street level	4 ft. 0 in.
Total minimum depth to invert of *lateral sewers in residence districts*	8 ft. 6 in.
For business districts, add for ordinary-depth basements	8 ft. 0 in.
Total minimum depth to invert of *lateral sewers in business districts*	12 ft. 6 in.

Hence, under average conditions, the depth of sanitary and combined pipe sewers of 12-inch diameter and less, should be not less than 8½ feet in residence districts, and 12½ feet in business districts. If, however, there is only a short stretch of low-lying ground on a residence street, it may be advisable to reduce the above depth, say to 6 feet as a minimun, when by so doing a very long stretch of sewer can be lessened that much in depth throughout, and a large saving in cost made thereby.



DEFLECTOR RING AND HUB OF SCREW PUMP, CHICAGO SYSTEM OF INTERCEPTING SEWERS

Erected at 39th Street Pumping Station

In the case of sanitary and combined sewers more than 12 inches in height, the above depths should be increased by the excess over 12 inches, for the house connections should enter near the top of the sewer.

In the case of storm sewers and of outlet and intercepting sewers, the depth will no longer be determined by the depth of basements alongside. In these sewers three other considerations determine the depth: (1) the depth at the upper end necessary to afford a good outlet for the sewage; (2) the grade necessary to give good velocity; (3) the depth necessary to prevent injurious heaving of the sewer foundations by frost.

In regard to the third point, no danger need be apprehended of the sewer itself freezing up, even if it be laid practically at the surface, for a stream of warm, flowing sewage will not freeze. There will be little or no danger of trouble from heaving, if the sewer foundation be four feet under ground; and many stretches of pipe sewers only two or three feet deep operate with entire satisfaction even in the northern United States.

19. Subdrains. It has already been stated that sewers should be made as nearly water-tight as possible. Otherwise there would be danger of the sewage leaking out so as to contaminate the adjacent soil. Hence, while it is not possible at any reasonable expense to make sewers *absolutely* tight, they should be built with the utmost care in this particular.

Yet, when due care is used in this respect, the sewer is made unfit for performing another important duty—that of draining away subsoil water so as to dry out unwholesome dampness from the soil, and especially from wet cellars and from under and around houses built on low ground.

In order to secure such drainage, and also, in case of wet ditches, to help remove water from the trenches during construction, it often becomes necessary or advisable to add to the sewer a *subdrain.*

A *subdrain* is a line of drain tile or sewer pipe laid with open joints, in the same trench with the sewer.

To allow connections with cellar drains to be made from both sides of the streets, the subdrain should be placed with its top a few inches below the bottom of the sewer; and to leave a firm foundation for the sewer itself, the subdrain should be placed a little to one side of the sewer.

With the above arrangement, special care should be taken to make the sewer joints tight, and there is some danger of slight leakage of sewage into the subdrain. Such leaks tend to stop themselves as time passes.

It is not safe to connect cellar drains directly with a sewer, even though they are trapped to prevent the sewer air from penetrating into and filling the pores of the soil under houses. In dry times, there may be no water running in the cellar drains; and at such times the water in a trap may evaporate so as to unseal it. Cellar and foundation drains should be connected to the subdrain instead of to the sewer itself.

The general relation of the subdrain to the sewer in the street, and the method of connecting it with the foundation drains, may be seen in Fig. 6.

In construction, the joints of the subdrain should usually be wrapped with muslin to prevent the entrance of mud and sand. The cloth, of course, does not last long; but by the time it rots, the soil around the tile will usually have become recompacted so that there is no longer danger of its getting into the drain. In quicksand, it may sometimes be necessary to fill in fine pebbles or broken stone around the subdrain.

20. House Connections. In Fig. 6 is also shown the method of connecting the sewer itself with the iron soil-pipe which drains the different plumbing fixtures, and which should extend at least 6 feet outside the basement wall. The house connection should be a line of 4-inch vitrified sewer-pipe, laid at right angles to the sewer, with tightly cemented joints, and if possible to at least a 2 per cent grade (that is, with a fall of 2 feet in 100 feet length). Some prefer 6-inch house connections; but these should not be allowed with 8-inch sewers, as the house connection may then allow obstructions to be carried to the street sewer large enough to catch therein and cause stoppages. At the sewer, the house connecton should turn down, by a 4-inch 45-degree elbow, into a 4-inch Y-junction laid so as to slant upward 45 degrees—all as shown in Fig. 7. This slant upward

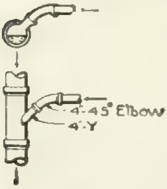


Fig. 7. Junction of House Connection with Sewer.

keeps the Y from affecting the smooth ordinary flow in the sewer.

In case the sewer is more than 12 feet deep below the street surface, the expense of digging down to it in making house connections would be so great that it is usually better, while the trench is open during sewer construction, to put in a *deep-cut house connection*, as shown in Fig. 8. In this case, sewer pipe must be used from the subdrain also, if such a drain is used; and care should be taken to turn the bells of the subdrain connection down so that the plumbers need make no mistake in the connections afterwards.

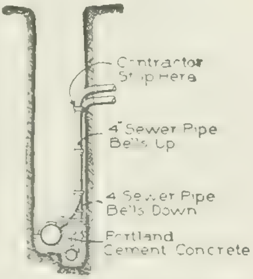


Fig. 8. Deep Cut House Connection.

In sewer construction, a Y-junction for a house connection (or a deep-cut house connection, if the sewer is over 12 feet deep), should be conveniently located opposite each lot on each side of the sewer; and the ends should be stopped with vitrified stoppers, covered over with sand and then cemented in. Full and accurate records must be kept of the exact locations of these connections, so that they can be found without trouble at any time.

No person should be allowed to cut or break into a pipe sewer for making house connections or any other kind of junction. If there is no Y or T-branch already set for the connection, a full length of pipe should be broken out and the proper Y or T-branch inserted A skilful workman can readily do this by breaking off one-half the bell of the new pipe, and of that of the old piece into which it must be inserted, and turning the new piece half around after insertion. The joints must then be re-cemented with great care.

21. Manholes. It has already been stated (Art. 16) that manholes must be placed at intervals along sewers, to permit of examination and repairs. These manholes are usually circular brick wells, with Portland cement concrete bottoms and heavy cast-iron covers, as shown in detail in Fig. 9. They must be large enough at the bottom, and for a couple of feet above the top of a pipe sewer, to permit a man to work comfortably. Four feet in diameter is a satisfactory size. Sometimes the manholes are made elliptical at the bottom, with the long axis lengthwise of the sewer; but this form is more difficult to build. Above the point mentioned, the sewer may be drawn in gradually to a diameter of about 2 feet 9 inches, at a point

2 feet 9 inches below the street surface, and thence narrowed more rapidly to about 20 inches diameter at the bottom of the cover casting.

The cover casting may be of any manufacturer's design satisfactory to the engineer, weighing at least 375 lbs. The lid should usually be perforated with 1-inch holes, to permit ventilation of the sewer; and immediately below it, there should be hung a heavy cast-iron *dustpan*, to catch any dirt entering through the perforations.

There should be a ladder of iron rungs built into the walls, as shown in Fig. 9.

The channels in the concrete bottom should be very carefully formed to give smooth, true, circular channels. They are sometimes lined with split sewer pipe. The benches at the sides of the channels should slope down towards the channels, as shown in the figure.

The concrete for the bottom may be made of 1 part Portland cement, 3 parts sand, and 5 parts of broken stone. All the brickwork should be laid with tight *shove joints,* in 1-to-3 Portland cement mortar; and the manhole walls should be plastered both inside and outside with 1-to-2 Portland cement mortar.

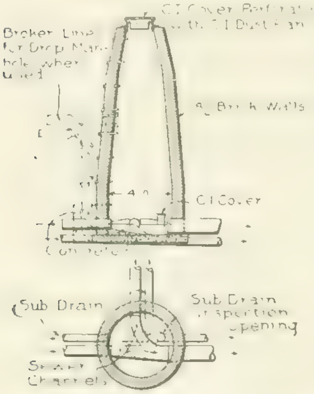

C.I. Cover Perforated with C.I. Dust Pan
Broken Line for Drop Manhole when used
8" Brick Walls
4 ft
C.I. Cover
Concrete
Sub Drain
Sub Drain Inspection Opening
Sewer Channels

Fig. 9. Sectional Elevation and Plan of Sewer Manhole.

Should sudden drops in the sewer be desirable, they can be made at *drop manholes,* in the manner shown by the broken lines of Fig. 9.

In the case of large masonry sewers, which often are many feet in diameter, the manholes may be joined directly to the masonry of the upper part of the sewer.

Opinions of sanitary engineers differ somewhat as to the distance apart at which manholes should be placed. In general, a manhole should be placed at all junctions of sewers, and at every change of grade or alignment in all sewers but those large enough to be entered readily for cleaning. This means that sewers should ordinarily be perfectly straight between manholes, to facilitate inspection and repairs, all changes in both grade and alignment being made at the manholes themselves.

Also, in any part of the system—such as in the business district—where it is especially objectionable to have the street dug up for repairs, manholes should be placed at least as often as every city block—that is, 300 to 400 feet apart. In the other parts of the system, some engineers leave out every other manhole where the grade and alignment are straight, putting manholes at least every two blocks. The intermediate manholes left out are replaced by *lampholes* (Art. 22) to save cost. In Figs. 4 and 38, the above arrangement of manholes is shown in two actual sewer systems.

22. Lampholes. The lampholes which, to save cost, are sometimes adopted in place of part of the manholes, consist each of a vertical line of sewer pipe, with cemented joints, reaching to the street surface, as in Fig. 10. Usually 8 inches is the minimum diameter for this pipe, which is cemented at the bottom into a regular sewer-pipe T-junction. Some concrete should be placed under and around this tee for a foundation. At the street surface, there should be an iron casting similar to a manhole casting, but smaller, as shown in Fig. 10.

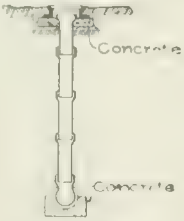


Fig. 10. Lamphole.

The earth, in refilling, needs to be very thoroughly tamped around the lamphole; and the lamphole casting should not be set until the material is thoroughly settled.

The object of the lamphole is to permit of inspection of the sewer, in determining whether it is clean and in locating stoppages. While its name suggests the lowering into it of a lamp, a beam of sunlight reflected into it from a mirror is more convenient.

A lamphole usually costs about $30 to $35 less than a manhole.

In Figs. 4 and 38 the above arrangement of lampholes in two actual sewer systems may be seen.

23. Flush-Tanks. Near the upper ends of sewers the flow of sewage is very small, sufficient only to make a shallow, trickling stream, liable not to be able to carry along the solid matter in the sewage so as to prevent deposits. An 8-inch lateral sewer in a residence district in a small town, even if laid at the minimum grade, would usually have an average depth of flow in the upper two and one-half blocks of less than one inch. Hence it is desirable, though not always absolutely necessary, to provide some special means for regularly flushing the upper portions of sewer laterals, to make them self-cleansing.

Again, in low-lying, level districts, it may be necessary, on account of the lack of fall, to lay the sewers at such slight grades that the velocity is insufficient to prevent deposits. Here, too, some special means should be provided for regularly flushing the sewers.

In the case of pipe sewers, such as are ordinarily used for the laterals in all systems, and for most of the mains in separate systems, the most efficient and reliable means for securing regular flushing is the use of automatic flush-tanks.

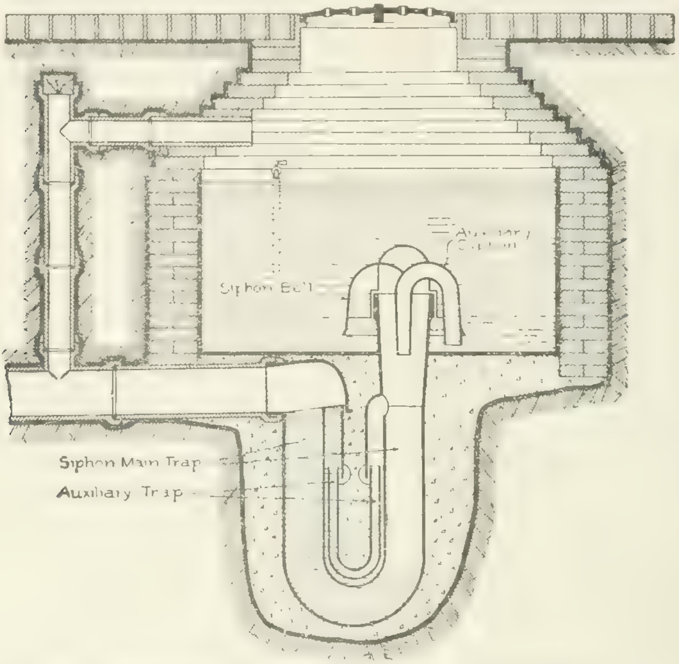


Fig. 11. Sewer Flush Tank with "De La Hunt" Adjustable Siphon.

A *flush-tank* is a masonry cistern built in the street, above the grade of the sewer, filled by a constantly running stream of water brought by a small pipe from the water-supply mains, and suddenly emptied by automatic devices into the sewer whenever the high-water line is reached.

Flush-tanks usually have a capacity of 150 to 500 gallons, and should approach the larger size named, to secure an efficient flush for two or three blocks. When made separate from manholes, flush-tanks are usually circular and of the general design of the masonry tank shown in Fig. 11. It is usually better, however, to combine the flush-tank with a manhole, as is shown by the masonry tank and manhole in Fig. 12. This permits inspection of the flush-tank and sewer, and is cheaper than to build manhole and flush-tank separate.

The bottoms of flush-tanks are usually of Portland cement concrete, and the walls of brick laid in Portland cement mortar. The tanks should be plastered inside and outside as described for manholes (see Art. 21). Special care should be used to make flush-tanks absolutely water-tight.

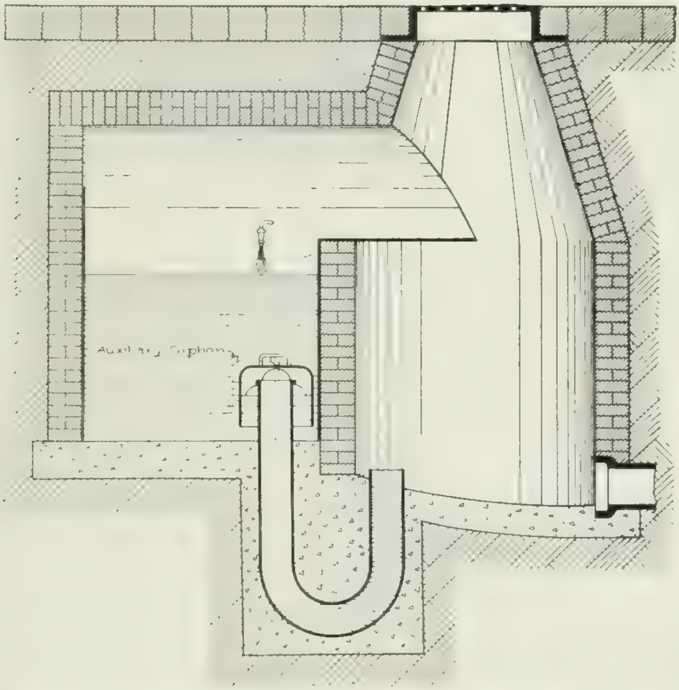


Fig. 12. Combined Flush Tank and Manhole with Special "Miller" Siphon.

The water is usually brought to the flush-tank by a ¾-inch galvanized pipe from the nearest water main. This pipe must be laid below the frost line (5½ to 7 feet deep, in the northern part of the United States), but should be turned up after it enters the flush-tank so as to discharge above the high-water line, as shown in Fig. 11.

The flush-tank may be prevented from freezing by being connected with the sewer above the high-water line, as shown in Figs. 11 and 12, so as to admit the warm air from the sewer.

It is a quite common practice to place flush-tanks at the heads of all laterals, as illustrated in Figs. 4 and 38. While some engineers dispute the necessity for this, it must be admitted that such an arrangement will be of great benefit, and its adoption is here advised for most cases.

In Fig. 38 the use of flush-tanks is shown at certain half-way points on the long laterals. The necessity for this arose from the fact that the sewers were not to be completed to the north ends of the laterals for some years after the southern portions were built.

The writer of this paper has used flush-tanks with success and great benefit, at intervals of about two or three blocks on sewers laid at grades below those considered necessary to make the sewers self-cleansing, though part of the flush from the intermediate tanks flows some distance upstream at each discharge.

The flush-tanks of a sewer system should be frequently inspected after the sewers are put into operation, and should be carefully kept in working order. The things needing most faithful watching are: first, the automatic discharging apparatus; and, second, the supply of water. The faucet admitting water may readily become choked up, putting the flush-tank out of service, or, on the other hand, may get wide open, wasting thousands of gallons of water every day.

24. Automatic Flushing Siphons. The reliability of flush-tanks in actual use will depend upon the frequency and care with which they are inspected and kept in working order, and especially on the reliability of the automatic discharging apparatus. No discharging apparatus having moving parts should be used in flush-tanks. Such apparatus is too likely to get out of order.

In Figs. 11 and 12, *sewer siphons* are shown for automatically discharging the flush-tanks suddenly whenever they fill to the high-water line. Such siphons have no moving parts whatever to get out of order, and should always be employed with flush-tanks.

In Fig. 11 the four ordinary parts of a flushing siphon are indicated. All four are usually iron castings, and must be air-tight. The *siphon bell* rests upon the *main trap*, which latter, together with the *auxiliary trap*, must be filled with water to the heights of the short legs, before the bell is placed in position. The main trap must be set plumb. The *auxiliary siphon* serves to ensure, at the end of the discharge, the *venting* of the siphon—that is, the free admission of air to the inside of the bell. With clear water, the auxiliary siphon is not always used; but it should be used whenever the siphon is to be used with raw sewage.

In the working of the siphon, the water in the flush-tank confines the air inside the bell and above the water in the main and auxiliary traps, and puts it under increasing pressure as the water rises. When the high-water line in the flush-tank is reached, this pressure becomes so great that the water in the auxiliary trap is forced down to the very bottom of the trap, and the confined air then blows out of the short leg of the auxiliary trap, thus releasing the air-pressure inside the bell, which up to this time has held back the water in the flush-tank. The water in the flush-tank then rushes out into the sewer through the main trap, and by siphonic action will continue to flow out until drawn down to the level of the bottom of the bell. Air then enters the bell through a small *sniff-hole* provided near the bottom of the bell for this purpose, *breaking* the siphonic action—that is, *venting* the siphon.

In case a siphon is used for raw sewage, there is often difficulty in securing satisfactory venting of the siphon at the close of the discharge; but this trouble can be remedied by using an *auxiliary siphon*, as shown in Fig. 11, and as illustrated by broken lines for the "Miller" siphon in Fig. 12.

In the *Miller siphon,* shown in Fig. 12, there is no auxiliary trap; but at high-water line the air-pressure in the main trap becomes so great that a bubble escapes, taking with it enough water from the short leg to start a sudden rush of water from the tank into the main trap, which suffices to establish siphonic action. This greatly simplifies the siphon; and the principle can be relied upon for siphons not larger than about eight inches internal diameter of the main trap. Larger siphons should have auxiliary traps.

In some siphons—as, for example, the *Rhoads-Miller*—the auxiliary trap is cast as a part of the main trap, out of which it opens below the floor of the tank, being entirely buried out of sight and reach in concrete. An objection to auxiliary traps such as shown in Fig. 11, is that they are inaccessible and may in time become stopped up. However, they make the action of large siphons more certain.

25. Hand-Flushing of Sewers. For large sewers, flush-tanks and siphons would have to be extremely large to be effective. Even in small sewers the effect of the flush will not be great for many blocks below the tank. Some engineers doubt the necessity for very extensive use of flush-tanks. When flush-tanks are not properly inspected and regulated (as to the feed faucet), they sometimes waste great quantities of city water. For these reasons, and sometimes to save cost, hand methods are sometimes relied upon for flushing sewers.

The most convenient, economical, and effective hand-flushing device is a connection with a water main by a water pipe of size large enough to flush the sewer very thoroughly. The only labor then required is that necessary for opening and closing the valves on this pipe. Such a flush, continuing much longer than the discharge of a flush-tank, can be made effective through a long stretch of sewer. The objections are the trouble and the danger of neglect inherent in hand work, and the usual greater length of time between flushings. To flush the sewers daily would be very expensive, both as to labor and as to the large amount of water needed.

Occasionally, very favorable local circumstances may permit of the admission at will of large volumes of water for flushing purposes from a stream or lake higher than the sewer.

In some cases, hand-flushing is done by temporarily damming up the sewage itself, and then suddenly releasing it when sufficient head has been secured.

A fire hose run to a manhole from a nearby hydrant may be the resort in other cases. In extreme cases, water has even been hauled to the sewer in tanks, for flushing.

26. Sewer Ventilation. More fear used to be felt of the danger of *sewer gas* (more properly termed *sewer air*, see Art. 1) in communicating disease, than medical knowledge warrants at the present time. Nevertheless, it is very important, not only from the sanitary but from many other points of view, that sewer air should be as pure as possible; and this requires good ventilation of the sewers. Fresh-air currents in the sewers should be maintained in some reliable way.

One method of securing this is to use perforated manhole covers (see Fig. 9). Objection is sometimes made to these as letting objectionable odors out into the street; but with well-designed and well-constructed sewers, well flushed and well ventilated, there will be no cause for complaint. If there are seriously objectionable odors from the manholes, such odors should be considered valuable as notices that the sewers are in dangerous condition, demanding immediate work to make them safe. Sewer air escaping into streets through manhole-cover perforations, is at once so diluted by fresh air as not to be dangerous to the health of passers by.

Another effective means for securing good ventilation is to extend the cast-iron soil-pipes (which form the main drainage pipes in the plumbing systems of houses) untrapped and full size through the roof. Figs. 4 and 35 show the omission of traps on the soil pipe. In Fig. 35, however, the use of a *disconnecting trap*, to disconnect the sewer air from that in the house plumbing pipes, is shown by broken lines. In case this is used, a ventilating pipe for the sewer should be extended up the sides of the house from the sewer side of the trap, and a fresh-air inlet provided on the house side, both as shown by the broken lines in Fig. 35.

The use of perforated manhole covers and untrapped soil pipes extending through the roofs, is all that is required to secure good ventilation of the sewers, the house connections, and the soil pipes themselves. Their use provides a large number of openings at different levels; and the temperature of the air in the sewers is practically always different from that above the ground. Hence air-currents are maintained for the same reason that chimneys cause draughts for fires, and a good circulation of air is maintained.

In the past, experiments in sewer ventilation have been made with tall chimneys, fan blowers, etc.; but such devices are entirely unnecessary, are very costly, and are usually unsuccessful on account of the very large number of openings into the sewer, which limit the air-currents produced by such devices to short distances.

27. Street Inlets and Catch-Basins. In the case of storm sewers and combined sewers, means must be provided for admitting the storm water to the sewers from the streets. For this purpose, either *street inlets*, as shown in Fig. 13, or *catch-basins*, as shown in Fig. 14, may be used. If the water can be allowed to flow one block safely in the surface gutters, the inlets for storm water would need to be only at each street intersection. In a few cases they need to be closer; but in many more cases the storm water can be carried in the gutters for two or even a greater number of blocks without injury, thus greatly reducing the number and cost of storm sewers and of inlets for storm water.

The simplest and least expensive arrangement for admitting storm water is the *street inlet*, which, as shown in Fig. 13, is a mere branch sewer, with a grated opening from the street. Besides costing less, the street inlet is often preferred for sanitary reasons, as it does not retain foul, unsanitary deposits, as does the catch-basin.

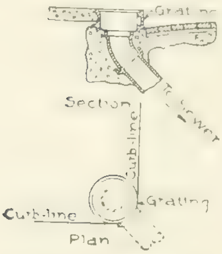


Fig. 13. Street Inlet

The *catch-basin*, shown in Fig. 14, is designed to catch the sand, dirt, and other heavy street detritus, and prevent their entering the sewer. Unless catch-basins are frequently cleaned, however (which is very seldom the case), they fail almost entirely in this; and as they are usually well filled with more or less foul deposits, they are condemned by many engineers.

When street inlets and catch-basins are left untrapped, as shown in Figs. 13 and 14, they assist in the ventilation of the sewers. This is sometimes objected to on account of the opportunity for the escape of foul odors, and traps are introduced in both, as shown by the dotted lines in Fig. 14, to prevent ventilation of the sewers through the storm inlets. If the sewers are kept in as good condition as they should be, there will be no good ground for such objections.

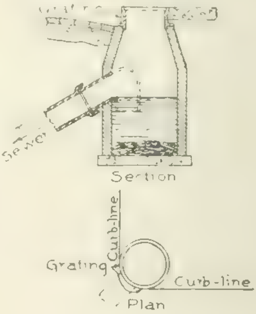


Fig. 14. Catch-Basin.

28. Inverted Siphons. It sometimes becomes necessary or desirable to carry a sewer down below the regular grade line, to pass under some obstacle or depression, and to raise it again to the regular grade line beyond. Such a stretch of sewer will necessarily flow full and be under some pressure. It is called an *inverted siphon*. The necessity for the use of the inverted siphon may be occasioned by some stream, by railway tracks, by another sewer, by a large water main, or sometimes merely by a low stretch of ground which happens to lie at such a level that the sewer cannot be carried across it at the regular grade.

Inverted siphons have often been constructed and operated successfully. It is wise, however, to take certain precautions in their design and construction, as otherwise serious trouble may be experienced with them.

First, as to material, it may be said that ordinary sewer pipe is not well suited to carry sewage under pressure, on account of the great difficulty in making absolutely tight joints, and on account of the brittle and unreliable nature of the pipe as to resistance to bursting pressures. If used under pressure, pipe sewers should be subjected to only a few feet of head, and all joints should be thoroughly encased in impervious Portland cement mortar and concrete, reinforced with imbedded steel bands. Brick masonry is still less suited to withstand bursting pressures. Ordinarily iron pipe should be used for inverted siphons.

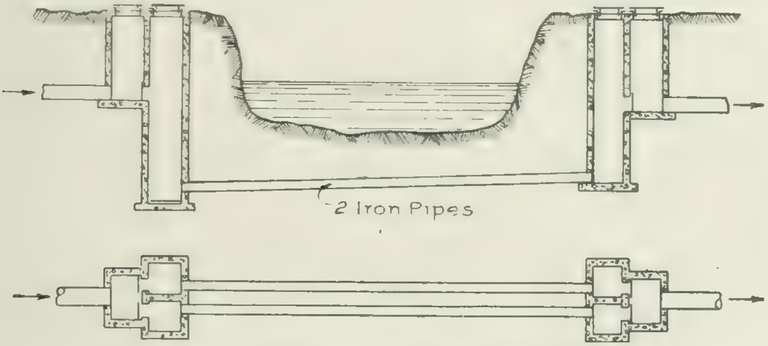


Fig. 15. Sectional Elevation and Plan of Inverted Siphon.

Second, it is especially important to insure a current in the inverted siphon sufficiently rapid to prevent deposits. If the flow is light at first, to increase afterwards, as is often the case, it is well to divide the siphon into two or more pipes with valves on each, so that the entire flow can be turned into one at first. If it is easy to add the second pipe in the future, it may often be left out at first. Thus in Fig. 38, the inverted siphon from the 18-inch outlet sewer to the septic tank is at present only an 8-inch cast-iron pipe, with provision for adding a 12-inch cast-iron pipe later.

Third, the design should be such as to permit ready access for inspection and removal of obstructions. The inverted siphon should if possible, be so planned that the flow of sewage can be diverted for a short time, either into one pipe, or entirely away from the siphon; and the siphon should drain to a low point from which the contents can be removed by gravity through a blow-off or by being pumped out. Where feasible, and especially where it will be very difficult (as under a stream) to dig down to the siphon in emergencies, the siphon should be made absolutely straight in grade and alignment, and a manhole placed at each end.

In Fig. 15 is shown an outline of an inverted siphon designed according to the above principles.

Where the siphon can readily be opened for repairs, as is the case with the one in Fig. 38, such expensive construction need not be resorted to. The one in Fig. 38, which carries sewage across low ground to a sewage tank about seven feet above the surface, is laid at an average depth of about six feet, and neither the grade nor the alignment is straight. It drains, however, to a low point, where a blow-off into a sewer is placed.

29. Outlets for Sewer Systems. We have heretofore discussed the house connection, and the laterals, submains, and main sewers, with their manholes, flush-tanks, and other accessories. We come next to the *outlet*, which, though not considered first here, would be one of the first things a sewerage engineer would have to consider in designing a sewer system.

Where possible, all of the sanitary sewage or combined sewage of the city should be led to one outlet, as the cost of disposing of it properly may be lightened thereby, and as the danger of injunction suits and other legal difficulties arising from damages from impurified or only partially purified sewage may be multiplied with the number of outlets. Often this will be possible by constructing comparatively short lengths of deep sewers where at first sight the topography would seem to make it impossible to secure one outlet. The size of the city, as well as the topography, will affect the number of outlets.

Storm sewage in the separate system can usually be discharged through a number of outlets into nearby natural watercourses.

Great effort should be made to secure an outlet or outlets for the sewer system low enough to drain all parts of the city by gravity. Pumping of the sewage or a material part of it, will mean a continuous expense involving an amount which would be sufficient to pay the interest on a large initial expense to secure a gravity outlet. Besides, there is the danger of such apparatus failing at critical times.

Usually effort is made to secure, if possible, an outlet into a considerable stream or body of water, even if the sewage is to be purified.

30. Sewage Disposal. Heretofore, sewage has been disposed of, in the great majority of cases, by simply emptying it into the largest available stream or body of water near at hand. Such serious contamination of natural waters has resulted from this practice, that at the present time much more attention than formerly is being paid to sewage purification; and usually the outlet plans should be made with the expectation that some method of purification will have to be adopted in the future, if not at present.

Sewage disposal is discussed further on, at much greater length (see Arts. 110 to 124). It will only be said here that the methods at present in favor almost all involve passing the sewage through large tanks, and then through some form of filter.

SEWER MATERIALS AND CROSS-SECTIONS

31. Sewer Materials. Sewers 24 inches in diameter and under, are usually built of *vitrified sewer-pipe.* A 24-inch pipe sewer, laid to a fall of 0.2 feet in 100 feet, will carry the sanitary sewage, under average conditions, of 29,000 people; and hence it is evident that in separate systems, all the sanitary sewers will be made of pipe, except a few main and outlet sewers in large cities. Considerable percentages of storm sewer and combined sewer systems will be pipe sewers also.

Occasionally *cement sewer-pipe* is used instead of the vitrified pipe.

Sewers 30 inches and larger in diameter, are most frequently built of *brick.* Pipe is sometimes used, however, for 30-inch to 36-inch sewers.

Concrete has of late years been growing in favor, to take the place of brick in sewer construction.

Stone was formerly used to a considerable extent for sewers; but on account of its roughness, and the great cost of cut-stone masonry, stone is suited only for backing brick linings in larger sewers. Even here, concrete would now ordinarily be employed, as both cheaper and better.

Occasionally, as in the case of submerged-outlet sewers into bodies of water, or sewers across marshes on soft foundations, *wooden stave pipe* is used for sewers. These pipes are made of pieces of timber, usually about two inches by four inches in size, put together breaking joints in the field, and hooped at regular intervals with iron bands which can be screwed tight. Wood should be used only where it will be wet all the time, to prevent rotting.

Cast-iron pipe, such as is used for water mains, is often adopted for short stretches of sewer under railways or streams where great strength is essential; for inverted siphons; and in cases where absolutely water-tight joints are essential, such as submerged lines in lakes, harbors, and stream crossings, or where there is much ground water.

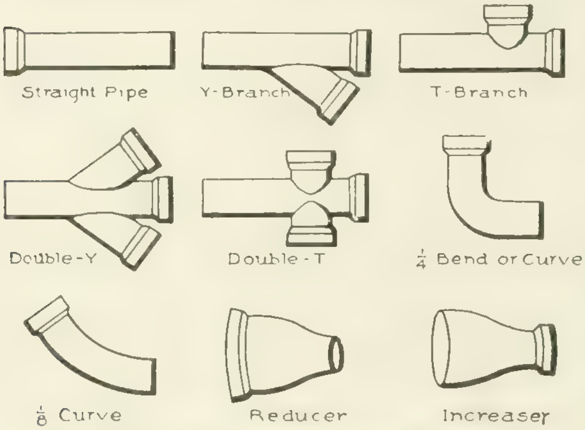


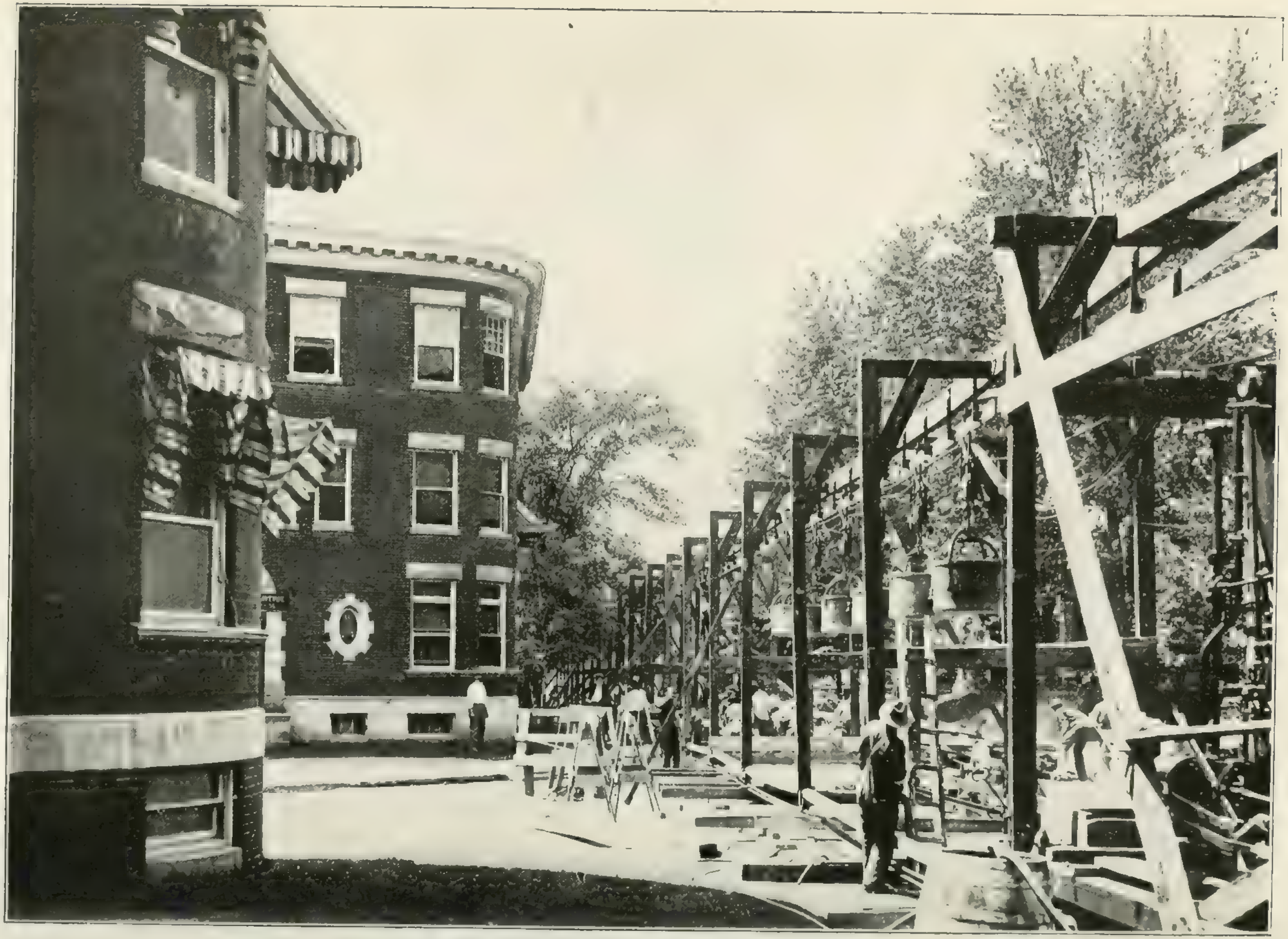
Fig. 16. Vitrified Sewer-Pipe and Specials

32. Vitrified Sewer-Pipe. Vitrified sewer-pipe has many excellent qualities for sewer use. It is hard, impervious, smooth, strong, does not decay or disintegrate, and is not affected by chemicals. It has few joints as compared with brickwork, and these joints are of convenient shape to make practically water-tight. Vitrified sewer-pipe is readily handled and laid in sewer construction. The materials of which it is made are widely distributed, and hence the cost of the pipe is reasonable.

In Fig. 16 are shown the general forms of the straight pipe and also of the special fittings (*sewer-pipe specials*) most commonly used in sewer construction.

In Table I (page 35) are given standard dimensions for straight sewer-pipe.

Vitrified sewer-pipe is made from shale clays, in very much the same way as brick and other clay products. The temperature at



TRENCH MACHINE IN OPERATION ON GORHAM AVENUE, BROOKLINE, MASSACHUSETTS

Metropolitan Water and Sewerage System of Boston.

which it is burned in the kilns must be very high, as in the case of paving brick, so as to produce an "incipient vitrification," a softening and running together of the particles of clay, which gives, on cooling, a very hard, impervious, and strong structure. Smoothness of interior and exterior surfaces is secured by the use of salt during the process of burning, so as to produce a "salt-glazed," glassy skin.

TABLE I

Standard Dimensions for Sewer Pipe

STANDARD				DOUBLE STRENGTH OR EXTRA THICK			
Inside Diam Inches	Thickness of Shell Inches	Depth of Socket Inches	Weight per Ft Lbs	Inside Diam Inches	Thickness of Shell Inches	Depth of Socket Inches	Weight per Ft Lbs.
8	¾	2½	22	8	⅞	2½	25
9	¾	2½	27	9	⅞	2½	30
10	⅞	2½	30	10	1	2½	34
12	1	2½	41	12	1⅛	3	50
15	1⅛	3	60	15	1¼	3	70
18	1¼	3	80	18	1½	3	100
20	1⅜	3	95	20	1⅝	3	120
21	1⅜	4	105	21	1¾	4	140
24	1⅝	4	135	24	2	4	180
27	2	4	215	27	2¼	4	240
30	2¼	4	270	30	2½	4	300
33	2⅜	4½	320	33	2⅝	4½	340
36	2½	5	365	36	2¾	5	390

The bells are made large enough to allow an annular space for cement, ranging from ⅜ inch thick for 8-inch pipe to ¾ inch for 36-inch pipe.

Smaller sizes of pipe, down to 3 inches in diameter, are made.

Double-strength pipe is used only in cases requiring unusual strength.

Vitrified sewer-pipe must be carefully inspected, piece by piece, just before being used in the sewer, all poor material being rejected. Some of the points to be noted in making the inspection are as follows:

(1) The pipe should be straight, and true in shape.

(2) The pipe must have a hard-burned, strong internal structure showing incipient vitrification. Small pieces may be chipped out of occasional lengths to test this; and the color will also be a guide after the inspector has become thoroughly familiar with the make of pipe being used.

(3) The hub and socket ends of adjacent pipes should fit together well, leaving at least the spaces for cement given under Table I.

(4) There must not be on the lower half of the interior of the sewer any lumps, blisters, or excrescences. A few may be allowed,

if not too large, if the pipe can be turned so as to bring them to the upper half.

(5) There must be no cracks extending into the body of the pipe, or of such nature as to weaken it materially. On tapping the pipe with a light hammer, if it does not give a clear ring, the presence of invisible cracks may be suspected.

(6) There must be no broken pieces of material size, from either the hub or the socket ends, nor any at all which cannot be turned to the upper half.

Nothing of human construction can be perfect, and sewer pipes are no exception to the rule. Hence the pipe inspector must have good judgment and considerable experience to draw the line properly between important and unimportant defects. In clause 25, Art. 93, of the sewer specifications given hereinafter, some definite rules are laid down to govern inspectors in this particular.

Vitrified pipe can be secured in 2, 2½, and 3-foot lengths. The longer the lengths, the fewer the joints, which is a material advantage.

33. Joints in Pipe Sewers. The joints are the weakest points in pipe sewers, and should be made with the utmost pains to secure as nearly as practicable an absolutely water-tight job. In Fig. 17, the upper joint shown illustrates the form commonly employed.

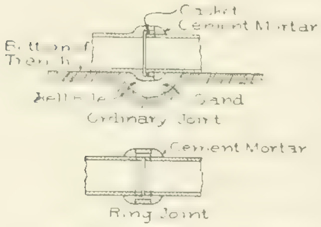


Fig. 17. Joints in Pipe Sewers

In the bottom of the trench, which should be rounded to fit the under part of the sewer pipe, *bell-holes* are dug for all bells, to permit the joint on the under side of the pipe to be made properly, and to give the pipe a bearing on its full length instead of merely on the bells. Before the spigot end of the pipe to be laid is *entered* into the bell of the last pipe laid, it should be wrapped with a *gasket* of hemp, oakum, or jute, as shown in Fig. 17, so that the inverts of the two pipes will match in a smooth line when the pipe is entered, and so as to prevent the soft cement mortar from being forced up through the joint to project into the pipe. The gasket also assists in making the joint water-tight, especially if there is water in the trench. Disastrous results have often followed the omission of the gasket, which should always be used.

After the pipe is entered and brought exactly to grade, Portland cement mortar, mixed about 1 to 1 or 1 to 2 with sand, should be *calked* into the joint, *to fill it absolutely full*, and should be beveled off on the outside, as shown in the figure. Special care should be taken on the under side of the pipe. *Immediately* after placing the cement, the bell-hole should be packed *full* of sand, so as to support the cement on the under side of the pipe till it has set. It is best to keep the cementing back two or three lengths of pipe from the pipe laying, to avoid danger of the cement being broken in placing the next pipe.

Without the most careful watching of every joint during construction, the workmen are sure to slight the joints. An inspector should be kept constantly on the work.

In the lower part of Fig. 17 is shown the *ring joint*, formerly preferred by some engineers, but now very seldom used. It is more costly than the ordinary form.

Various joints have been invented and used to a limited extent, which include simple beveling of the ends of the pipe without using bells, the use of grooves at one end with corresponding projections at the other end, etc. Sometimes the exterior of the spigot end and the interior of the bells are grooved and made rough in the ordinary form of joint. This is an advantage in holding the cement, and in securing a water-tight job.

34. Cement Sewer-Pipe. Ever since the early use of pipe sewers in the latter half of the nineteenth century, cement pipe has been used to some extent for sewers; and recently there seems to be a revival and extension of its use. Experience has shown that cement is a very suitable material for making sewer pipe, and that cement pipes, when well made, of first-class materials, give excellent satisfaction for sewers, and are durable and not disintegrated by the sewage.

The manufacture of good cement sewer-pipe, however, cannot be successfully carried on by men who do not have the necessary skill, which is to be gained only by experience in this particular work; and even skilled manufacturers will not be successful unless both the cement and the sand used are of first-class quality, nor unless plenty of cement is used. Much poor cement pipe has been made, because these almost self-evident facts have not been understood; and in this way cement sewer-pipe has gained a bad reputation in many localities.

In general it may be said that the sand should be clean, sharp, and coarse, and that it should contain a considerable proportion of fine pebbles, smaller than a cherry-pit. Only the best Portland cement should be used, and the mortar should not be weaker than 1 to 3. The mixing must be very thorough, as also the tamping into the moulds.

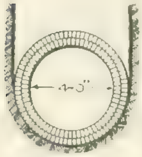


Fig. 18. Circular Brick Sewer, Ingersoll Run, Des Moines, Iowa.

Two general kinds of cement sewer-pipe are made. In one, just coming into use, the pipes are made continuously in the ditch. A form of moulds is used to give the correct shape and size, which can be forced ahead as the work progresses; and there are no joints. It is too soon yet to tell how successful this plan may be.

In the more common form of cement sewer-pipe, the pipes are made in a factory, in pieces of the same length as vitrified pipe. Usually, comparatively little water is used in mixing, in order to permit immediate removal of the pipe from the moulds. While such pipe are *curing* (setting), the omitted water must be supplied by frequently wetting them, or the process of setting and hardening cannot go on properly. Many cement sewer-pipes of this kind are spoiled in the curing.

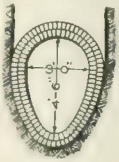


Fig. 19. Egg - Shaped Brick Combined Sewer.

Cement pipe are now made with bells for the joints, the same as vitrified pipe. The manufacture of specials, such as the Y-junctions required in such numbers for house connections, is still in unsatisfactory condition.

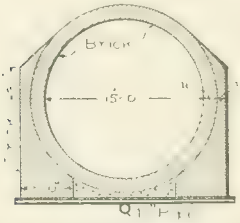


Fig. 20 Circular Brick Sewer with Subdrain, 64th Street Brooklyn, N. Y.

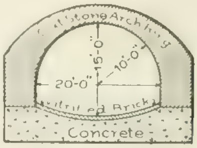


Fig. 21. Section of a Large Sewer in St. Louis, Mo.

The body of a cement sewer-pipe is of much weaker material than that of which vitrified pipe are made; and the thickness of cement pipe should be much greater than the thickness given in Table I for vitrified pipe.

35. Typical Cross-Sections of Large Sewers. In Figs. 18 to 25, inclusive, are shown some typical designs for sewers too large to be constructed of sewer pipe.

In Fig. 18, the common circular form is shown. This form is more economical to construct than any other when good foundations can be had, for the circle gives a larger area and velocity of flow when full than any other shape having the same circumference.

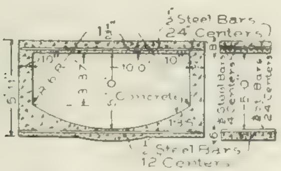


Fig. 22. Ingersoll Run Sewer with Low Headroom, Des Moines, Iowa.

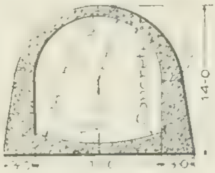


Fig. 23 Dry Run Sewer, Waterloo, Iowa.

In the case of combined sewers, however, the dry-weather flow of sewage is so very small, in comparison with the size of the sewer, that it makes only a shallow, trickling stream of little velocity, and the sewer will not be self-cleansing. For such sewers, this difficulty can be overcome by the use of the egg-shape of sewer, shown in Fig. 19. This shape has a circular invert having a radius only half that of the top; and the depth and velocity of the dry-weather flow will be the same as in a circular sewer of this smaller radius, while at the same time the capacity in time of flood is equivalent to a much larger circle.

In Fig. 20, a favorite type of design for very large circular sewers is shown. For such large sewers, the upper half constitutes an arch, which exerts heavy pressures or thrusts horizontally outward against the sides of the sewer at the height of the center. To withstand these thrusts, the masses of masonry backing shown in the figure are added. This backing may be of brick, rubble-stone, or concrete masonry.

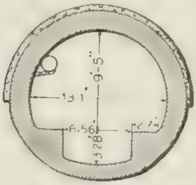


Fig. 24. Old Type of Main Sewers. Paris France.

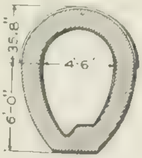


Fig 25 New Type of Sewers, Paris, France.

In the large sewers, too, it usually is not practicable to round the bottom of the trench to fit the circular shape, as is done for smaller sewers; and hence the flat foundation, also shown in the figure, is adopted. In soft materials, it often becomes necessary to drive piles to carry the weight of sewers.

In Fig. 21 is shown the favorite design for large sewers. For reasons given in discussing Fig. 20, the foundation is necessarily made flat; and with this shape of foundation, Fig. 21 will give a larger area and capacity for the same amount of material than Fig. 20, other conditions being the same. Also, Fig. 21 requires less headroom than Fig. 20 for the same capacity—which is often of great importance in the case of these large sewers. The invert of Fig. 21 is not so well suited to prevent deposits as that of Fig. 20; but in the case of these large sewers, there is usually a large flow even in dry weather, so that this point may be of little importance.

In Fig. 23 we have an example of the use of concrete for a large sewer of the general type shown in Fig. 21, and just discussed.

In Fig. 22 we have an extreme case of low headroom, secured by making the top an absolutely flat slab of concrete, reinforced with steel. In this case the bottom of the sewer was necessarily located at a very shallow depth below the street, while the required size of sewer was large.

Finally, in Figs. 24 and 25, are shown two typical cross-sections of the famous sewers of Paris. The large main shown in Fig. 24 acts not only as a sewer, but also as a subway for the water mains and for other purposes. The entire ordinary flow of sewage is confined within the *cunette*, or comparatively small channel shown in the bottom. The ledge on each side serves for the passage of workmen and of cleaning carts, flushing devices, etc. The section shown in Fig. 25 is a later type, and is more nearly self-cleansing. The dirt in the streets is washed into these sewers by the use of hose, and special conveniences for cleaning it out of the sewers are needed.

36. Junction=Chambers for Large Sewers. Where two or more large sewers join, special difficulties present themselves, in providing supports for the partial arches whose supports are cut away in making the junction. It is usually necessary, when the sewers are large, to build a masonry chamber enclosing the entire junction, and with a self-supporting roof spanning all the sewers.

Various designs for such junction-chambers are used, but the most common type is illustrated in Fig. 26. Here a *bell-mouth arch* is used to span the opening, the case being the junction of three of the Chicago intercepting sewers (see Fig. 5). Sometimes *flat roofs* are used, supported by steel beams or made of reinforced concrete.

The bottoms of such junctions are the *mathematical intersections*, executed in masonry, of the lower halves of the sewer channels; and for sewers not too large, the upper halves may sometimes be built in a similar way, or with *vault ribs*, as in the roofs of old cathedrals.

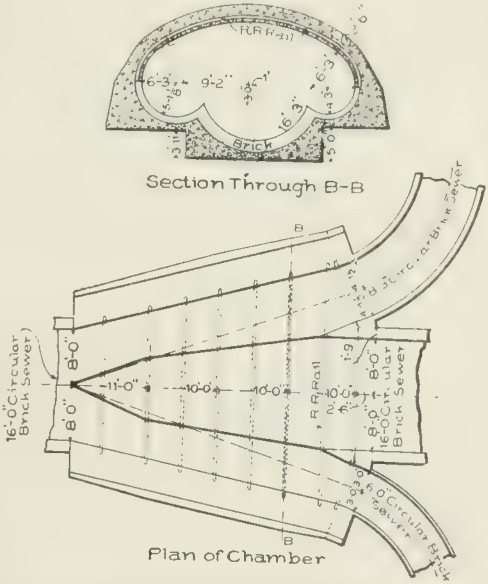


Fig. 26. Junction of Brick Sewers, Lawrence and Sheridan Avenues, Chicago, Ill.

37. Brick Sewers. It has already been stated that brick is the favorite material for sewers too large to be made of pipe, the dividing line usually being drawn at 30 inches to 36 inches diameter. Brick present many advantages for sewer work, including their moderate cost, their durability, and their small size and regular shape, which enable them to be readily handled and used in building sewers of any desired cross-section, with comparatively smooth and true interior surfaces.

Sewer brick, as those suitable for sewer construction are commonly called, should be harder burned than ordinary building brick, to enable them to stand the wear from the flow of sewage, and to insure against disintegration. They need not, however, be as hard burned as No. 1 paving brick, and hence constitute an intermediate grade between building brick and pavers. Sewer brick should be uniform in size, and of regular, true shape, so as to permit of being laid with thin joints, to form smooth, true surfaces. They should be carefully inspected on the work just before being used, and all defective brick thrown out. The common size for sewer brick approximates 8½ by 4 by 2¼ inches.

In the sewer, the brick are laid in rings, as shown in Figs. 18 and 19, with the 4-inch dimension radial and the 8½-inch dimension lengthwise of the sewer. Care should be taken to *break joints* in each ring. The brick should be laid in Portland cement mortar, made of at least 1 part of cement to 3 parts of clean, sharp sand of medium-sized grains. Pebbles should be screened out of the sand so as to permit thin joints. All joints should be filled *full* of mortar, the brick being laid with *shove joints,* to make a practically water-tight job. The outside ring of the invert should be laid against a layer of 1 to 2 Portland cement mortar; and the outside of the arch (or upper half of the sewer) should be plastered with the same mortar, to keep out ground water. Similarly, to prevent leakage of sewage, the entire interior surface of the sewer should be plastered with the same mortar, or else thoroughly washed with at least two coats of liquid cement, after the joints have been carefully pointed and smoothed. Even with the utmost care, it will be found impossible to secure absolute watertightness; and the difficulties will be especially great when ground water and soft materials are encountered in the trench.

Up to 6 or 7 feet diameter, two rings of brick are usually sufficient. In fact, for the smaller sizes of brick sewers, one ring would be amply strong with firm foundations; but it is difficult to make the sewer sufficiently tight when only one ring is used, because all joints extend entirely through. Sometimes an exterior layer of concrete may be used to meet this objection, at least for the lower half of the sewer; or an outside ring of brick may be used for the invert only. Sewers larger than 6 or 7 feet in diameter usually require three rings of brick; and more are needed for very large sewers, for which the number required must be calculated for each particular case to suit the special conditions.

38. Concrete Sewers. Of late years, concrete has frequently been employed in preference to other kinds of masonry for many purposes, of which sewer construction is one. Its advantages for sewers are many. The following may be mentioned:

First, and foremost, the cost is usually less than the cost of brick masonry.

Second, the concrete exactly fits the irregularities of the excavation, giving better foundations.

Third, sewers built of concrete constitute a solid structure without joints, and hence are less liable to uneven settlement.

Fourth, there are no joints, as in brickwork, to be made watertight, though, on the other hand, it is not easy to make the body of the concrete entirely impervious to seepage.

Fifth, the concrete can be readily moulded to any desired shape of sewer.

Sixth, the concrete can be made by comparatively unskilled workmen, if skilled foremen are employed.

Concrete may be used for foundations, as shown in Figs. 20 and 21; for the backing of brick sewer rings; and in various other combinations with brick; or it may be used for the entire sewer, as in Figs. 22 and 23.

Reinforced concrete, or concrete reinforced with steel rods, to prevent cracks from tension stresses, has opened up of late years entirely new possibilities in sewer construction, of which Fig. 22 is an example.

It has been reported that the concrete invert of the large St. Louis sewer shown in Fig. 21 has shown surface pitting and disintegration from the effects of the sewage. This is a trouble which does not appear to have been experienced elsewhere, and hence is presumably uncommon, and would seem due most probably to poor materials or poor workmanship. Danger from this source could be prevented by lining the concrete sewer with one ring of vitrified paving brick.

FORMULÆ AND DIAGRAMS FOR COMPUTING FLOW IN SEWERS

39. Formulæ for Computing Flow in Sewers. It has already been stated that more than 99.8 per cent of even sanitary sewage is simply ordinary water which has been added to the foul wastes to assist in removing them. Hence the mathematical formulæ for the flow of sewage are the same as those for the flow of water. They may be studied in detail in the instruction paper on Hydraulics.

Two general hydraulic formulæ have commonly been employed in sewer computations, as follows:

(1) *Weisbach's Formula.* The older computations were generally based on Weisbach's formula, which is as follows:

$$v = \sqrt{\frac{2gh}{1 + e + c\frac{l}{d}}}.$$

In the above formula,

v = Average velocity of flow, in feet per second.

g = Acceleration due to gravity = 32.2 ft. per second.

h = Fall of sewer, in feet.

e = Coefficient of entrance = 0.505.

c = Coefficient of friction in pipe = $0.0144 + \frac{0.0169}{\sqrt{v}}$.

l = Length of pipe, in feet.

d = Diameter of pipe, in feet.

Weisbach's formula has been much used for sewer computations, for the reason that Mr. Baldwin Latham, in the first treatise on Sanitary Engineering worthy the name (1873), published extensive tables of flow, calculated from this formula, which made sewer computations very simple. Hence it was easier for later engineers simply to make use of these tables than to compute new ones of their own.

(2) *Kutter's Formula.* In later hydraulic computations, it has generally been considered that Kutter's formula gives the most reliable results. It is as follows:

$$v = c\sqrt{RS} = \left[\frac{41.66 + \frac{1.811}{n} + \frac{.00281}{s}}{1 + \left(41.66 + \frac{.00281}{s}\right)\frac{n}{\sqrt{R}}}\right]\sqrt{RS}.$$

In this formula,

v = Average velocity of flow, in feet per second.

R = Mean hydraulic radius in feet = Area of cross-section of stream in square feet, *divided by* wetted perimeter, in feet, of length of portion of circumference of channel wet by the stream. (Note.—For circular pipe sewers, $R = \frac{1}{4}$ of the diameter when the pipe is flowing either full or half-full.)

S = Slope of the sewer = $\frac{\text{Fall}}{\text{Length}}$.

n = Coefficient of roughness, varying with the roughness of the channel.

For pipe sewers it is common to assume that $n = 0.013$; and for brick sewers, that $n = 0.015$. For cement pipe sewers, the roughness might be considered intermediate between these values of n, but $n = 0.013$ is generally used for them as well as for clay pipe. New and perfectly clean channels would not be so rough as indicated by these numbers, but the growths and deposits which may accumulate in sewers render it wise to adopt the above values for n.

Both the above sewer formulæ give merely the average velocities (v) of flow. *To obtain the discharge in cubic feet per second, we must multiply "v" by the area in square feet of the cross-section of the stream of sewage.*

Kutter's formula gives less capacities for pipe sewers than Weisbach's for the small sizes, up to about 18 inches' diameter. It will be on the safe side to adopt Kutter's formula; and this is now very generally done, though actual gaugings of small pipe sewers either new or in very good condition, may often show greater velocities and capacities than the formula would indicate, when the values of n above given are adopted.

In this paper, Kutter's formula will be adopted as the basis of all calculations of the flow of sewers.

40. Diagram of Discharges and Velocities of Circular Pipe Sewers Flowing Full. Direct numerical computations of flow in sewers from the formulæ given above, would be very laborious and tedious. The work may be very greatly simplified by the use of tables or diagrams. Diagrams are more convenient than tables, and are adopted for this paper. With their aid, computations of flow in sewers are very easy and short.

Fig. 27 is such a diagram, giving the capacities and velocities of circular *vitrified* pipe sewers flowing full. *Cement* pipe sewers would probably have discharges and velocities somewhat less than those shown in this figure.

TO USE THE DIAGRAM

(*A*) *When the diameter of the pipe and the grade are given, to find the discharge and the velocity.*

(1) Look along the bottom horizontal line till the grade is found, interpolating by the eye, if necessary, between the grades marked on the diagram. (2) Find the point where the vertical line through the given grade intersects the inclined line marked with the given diameter of sewer. (3) Trace horizontally through this point, interpolating by the eye, if necessary, between the horizontal lines on the diagram; and read the discharge of the pipe running full, on the left side of the diagram in cubic feet per second, or on the right side of the diagram in gallons per 24 hours. (4) If the velocity is desired, it can be determined by noting where the point (found in 2, above) of intersection of the given grade and diameter lines falls with reference to the inclined lines marked with the different velocities, estimating by the eye the decimals of a foot per second.

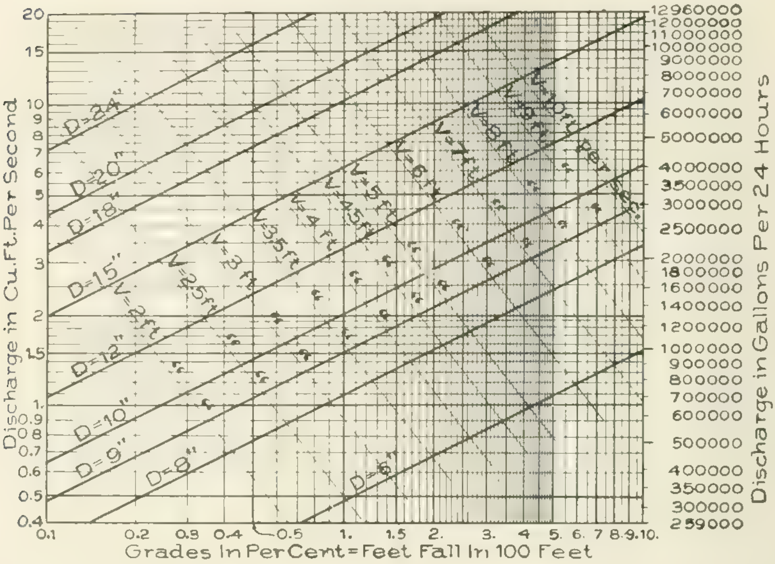


Fig. 27. Discharges and Velocities of Circular Vitrified Pipe Sewers Flowing Full. By Kutter's Formula ($n = 0.013$).

(*B*) *When the grade and the required discharge are given, to find the necessary diameter of pipe, and the velocity.*

(1) Look along the bottom horizontal line till the given grade is found, interpolating by the eye, if necessary, between the grades marked on the diagram. (2) Find the intersection of the vertical line through this grade with the horizontal line through the given discharge, finding the discharge on the left of the diagram if it is given in cubic feet per second, or on the right if it is given in gallons per 24 hours. (3) Note between which two diameter lines this point of intersection falls, and take the diameter line nearest as that required. (4) Also note the position of the point of intersection with reference to the velocity lines, and so estimate the velocity, interpolating by the eye between the inclined velocity lines.

(*C*) *When the velocity and diameter are given, to find the grade and discharge.*

(1) Find the intersection of the given diameter line with the given velocity line, interpolating by the eye, if necessary. (2) Then vertically downward to the bottom of the diagram from this point of intersection, read the required grade; and horizontally to the left side or to the right side of the diagram, read the discharge, interpolating by the eye in each case, if necessary.

All other cases may be solved by similar obvious methods.

EXAMPLES

Example 1. What will be the discharge and velocity of a 15-inch pipe sewer laid to a 0.2 per cent grade?

Solution. See *A*, above. From the intersection of the vertical 0.2 per cent grade line with the inclined 15-inch diameter line, we read horizontally to the left the discharge of 2.8 cu. ft. per second, or to the right, of 1,850,000 gallons per 24 hours. We further note that the point of intersection of the 0.2 per cent grade line with the 15-inch diameter line falls between the 2.0 and the 2.5 ft. per second velocity lines, and by the eye we estimate the velocity to be 2.3 ft. per second.

Example 2. See *B*, above. What size of pipe sewer laid at a grade of 0.5 per cent will be required to carry an average flow of 200,000 gallons of sewage per day, the maximum rate of discharge being three times the average? (NOTE.—Hence use 600,000 gallons discharge in solving the example.) Also, what will be the velocity?

Answer. Required diameter of sewer, 9 inches; velocity of flow, about 2.3 ft. per second.

Example 3. See *C*, above. If the minimum allowable velocity of flow is 2 ft. per second when a sewer flows full, what minimum grade will be required to produce this velocity in a 12-inch sewer?

Answer. 0.23 per cent minimum grade.

Example 4. If an outlet sewer serves 20,000 people, each person contributes 100 gallons per day, and the maximum rate of flow is 3 times the average, what size of sewer will be required, if its grade is 0.25 per cent?

Answer. 24 inches diameter.

Example 5. If an 8-inch pipe sewer is laid at a 0.45 per cent grade, what will be the discharge and the velocity when it flows full?

Answer. 480,000 gallons per day; 2.1 ft. per second.

Example 6. A storm pipe sewer drains 10 acres, and should be able to carry 1.5 cu. ft. per second per acre. Its grade is 0.5 per cent. What diameter will be required?

Answer. 24 inches diameter.

41. Diagram of Discharges and Velocities of Circular Brick and Concrete Sewers Flowing Full. Fig. 28 is the diagram for circular brick and concrete sewers, corresponding to Fig. 27 for pipe sewers, and is used in the same way.

TO USE THE DIAGRAM

(*A*) *When the diameter of the pipe and the grade are given, to find the discharge and the velocity.*

(1) Look along the bottom horizontal line till the grade is found, interpolating by the eye, if necessary, between the grades marked on the diagram. (2) Find the point where the vertical line through the given grade intersects the inclined line marked with the given diameter of sewer. (3) Trace hori-

zontally through this point, interpolating by the eye, if necessary, between the horizontal lines on the diagram; and read the discharge of the pipe running full, on the left side of the diagram in cubic feet per second, or on the right side of the diagram in gallons per 24 hours. (4) If the velocity is desired,

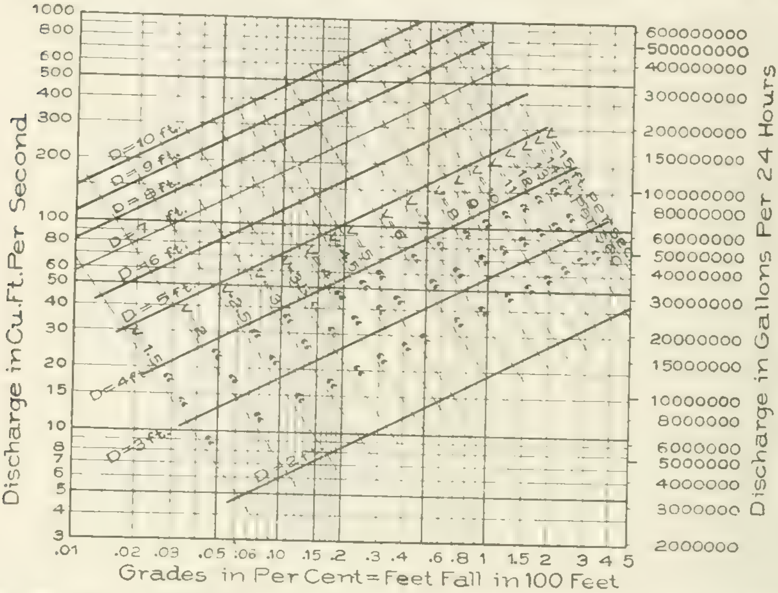


Fig. 28. Discharges and Velocities of Circular Brick and Concrete Sewers Flowing Full By Kutter's Formula ($n = 0.015$).

it can be determined by noting where the point (found in 2, above) of intersection of the given grade and diameter lines falls with reference to the inclined lines marked with the different velocities, estimating by the eye the decimals of a foot per second.

(*B*) *When the grade and the required discharge are given, to find the necessary diameter of pipe, and the velocity.*

(1) Look along the bottom horizontal line till the given grade is found, interpolating by the eye, if necessary, between the grades marked on the diagram. (2) Find the intersection of the vertical line through this grade with the horizontal line through the given discharge, finding the discharge on the left of the diagram if it is given in cubic feet per second, or on the right if it is given in gallons per 24 hours. (3) Note between which two diameter lines this point of intersection falls, and take the diameter line nearest as that required. (4) Also note the position of the point of intersection with reference to the velocity lines, and so estimate the velocity, interpolating by the eye between the inclined velocity lines.

(*C*) *When the velocity and diameter are given, to find the grade and discharge.*

(1) Find the intersection of the given diameter line with the given velocity line, interpolating by the eye, if necessary. (2) Then vertically

downward to the bottom of the diagram from this point of intersection, read the required grade; and horizontally to the left side or to the right side of the diagram, read the discharge, interpolating by the eye in each case, if necessary.

All other cases may be solved by similar obvious methods.

EXAMPLES

Example 7. What size of circular brick or concrete sewer laid to a 0.2 per cent grade will be required to carry a storm sewage flow of $\frac{3}{4}$ cu. ft. per second per acre from one square mile of drainage area, and what will be the velocity?

Solution. See *B*, above. 1 square mile = 640 acres. The capacity required is $640 \times \frac{3}{4} = 480$ cu. ft. per second, which we find on the left of Fig. 28 just below the 500 cu. ft. per second horizontal line, interpolating by eye. We next find the 0.2 per cent grade line at the bottom of the diagram, and locate the point of intersection of this vertical 0.2 per cent grade line with the horizontal 480 cu. ft. per second line already found above. This point of intersection comes nearly on the 9 feet inclined diameter line, and between the seven and eight feet per second inclined velocity lines.

Answer. Diameter of sewer required, 9 feet. Velocity = 7.6 ft. per second.

Example 8. What will be the minimum grade for a 60-inch brick or concrete sewer, if the minimum velocity allowed when flowing full is 3 ft. per second?

Answer. See *C*, above. 0.067 per cent grade.

Example 9. How large a population, contributing 75 gallons per capita per day of sanitary sewage, on the average (the maximum flow being 3 times the average), can be served by a 48-inch circular brick sewer, laid to a 0.06 per cent grade; and what will be the velocity of flow? (NOTE: Find the capacity as in *A*, above; and then divide by 3 times the average per capita amount per day.)

Answer. 89,000 population. 2.4 ft. per second.

Example 10. What will be the grade required to force a flow of 500 cu. ft. per second through a 96-inch circular brick sewer?

Answer. 0.38 per cent grade.

42. Diagram of Discharges and Velocities of Egg-Shaped Brick and Concrete Sewers Flowing Full. Fig. 29 is the diagram for egg-shaped brick sewers, corresponding to Fig. 27 for circular pipe sewers, and to Fig. 28 for circular brick and concrete sewers.

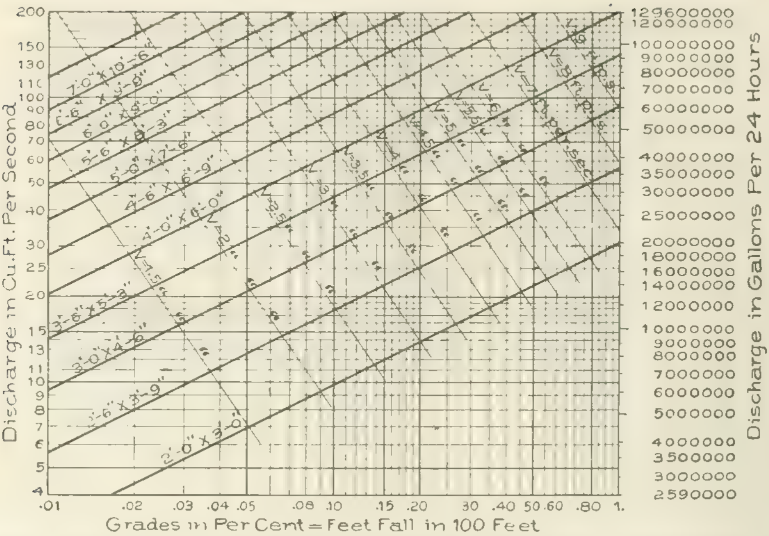


Fig 29. Discharges and Velocities of Egg-Shaped Brick and Concrete Sewers Flowing Full By Kutter's Formula (*n* = 0.015)

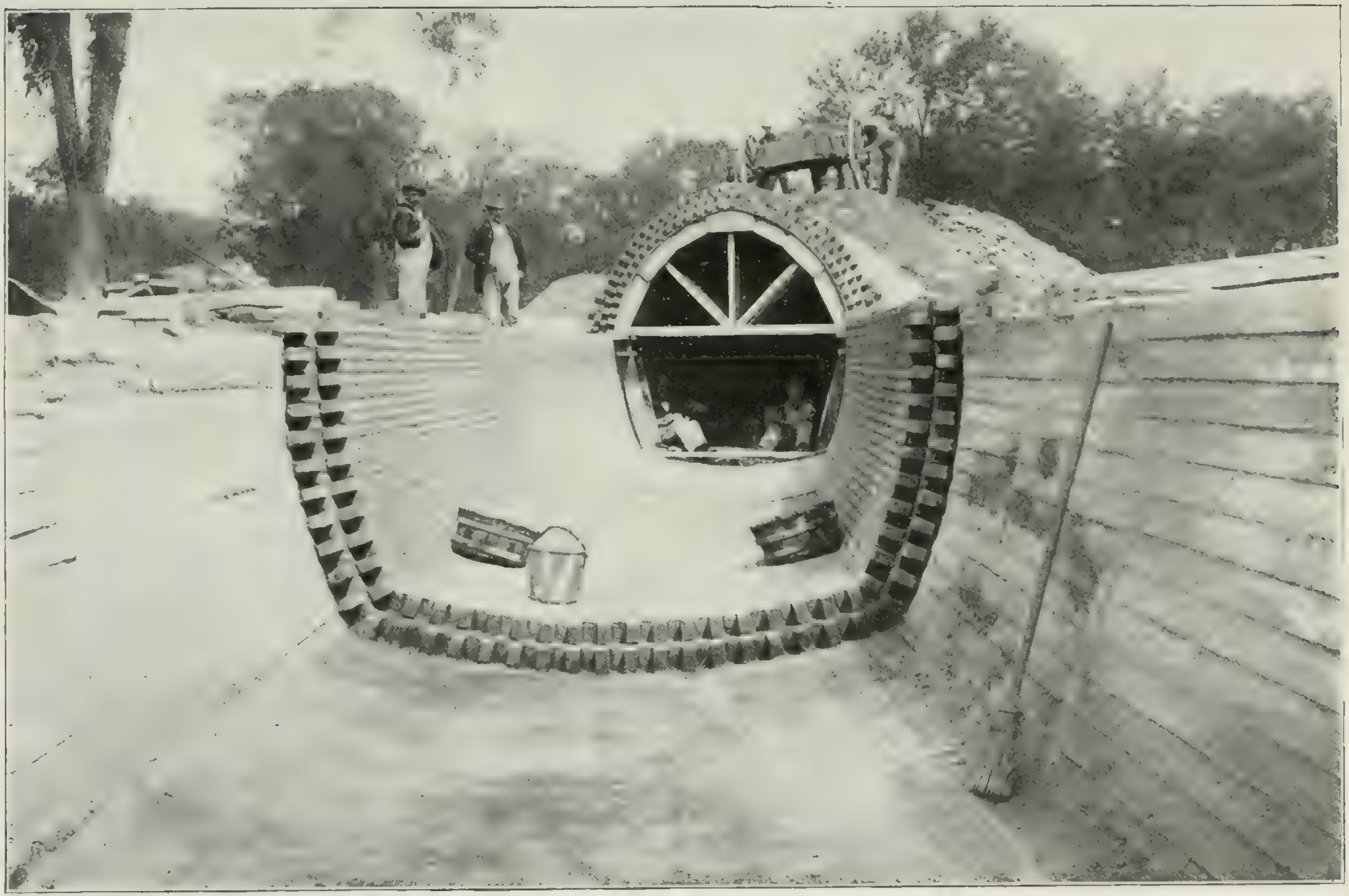
TO USE THE DIAGRAM

(*A*) *When the diameter of the pipe and the grade are given, to find the discharge and the velocity.*

(1) Look along the bottom horizontal line till the grade is found, interpolating by the eye, if necessary, between the grades marked on the diagram. (2) Find the point where the vertical line through the given grade intersects the inclined line marked with the given diameter of sewer. (3) Trace horizontally through this point, interpolating by the eye, if necessary, between the horizontal lines on the diagram; and read the discharge of the pipe running full, on the left side of the diagram in cubic feet per second, or on the right side of the diagram in gallons per 24 hours. (4) If the velocity is desired, it can be determined by noting where the point (found in 2, above) of intersection of the given grade and diameter lines falls with reference to the inclined lines marked with the different velocities, estimating by the eye the decimals of a foot per second.

(*B*) *When the grade and the required discharge are given, to find the necessary diameter of pipe, and the velocity.*

(1) Look along the bottom horizontal line till the given grade is found, interpolating by the eye, if necessary, between the grades marked on the diagram. (2) Find the intersection of the vertical line through this grade with the horizontal line through the given discharge, finding the discharge on the left of the diagram if it is given in cubic feet per second, or on the right if it is given in gallons per 24 hours. (3) Note between which two diameter lines this point of intersection falls, and take the diameter line nearest as that required. (4) Also note the position of the point of intersection with reference to the velocity lines, and so estimate the velocity, interpolating by the eye between the inclined velocity lines.



BOTTOM OF TRENCH OF CONCRETE AND BRICK-LINED SEWER

The entire work is covered with an earth embankment after completion. Metropolitan Water and Sewerage System of Boston, Mass.

(*C*) *When the velocity and diameter are given, to find the grade and discharge.*

(1) Find the intersection of the given diameter line with the given velocity line, interpolating by the eye, if necessary. (2) Then vertically downward to the bottom of the diagram from this point of intersection, read the required grade; and horizontally to the left side or to the right side of the diagram, read the discharge, interpolating by the eye in each case, if necessary.

All other cases may be solved by similar obvious methods.

EXAMPLES

Example 11. What will be the discharge and velocity of flow of a 4 by 6-feet egg-shaped brick or concrete sewer flowing full and laid to a 0.4 per cent grade?

Solution. See A, above. Find the 0.4 per cent grade line at the bottom of Fig. 29, and locate the point of intersection of the vertical line through this point with the inclined 4 by 6 dimension line. Then tracing horizontally to the left, we estimate by the eye 128 cu. ft. per second for the discharge. We also note that the point of intersection of the vertical 0.4 per cent grade line with the inclined 4 by 6 dimension line found above, is practically on the inclined 7 ft. per second velocity line.

Answer. Discharge, 128 cu. ft. per second. Velocity, 7 ft. per second.

Example 12. What will be the size of egg-shaped brick or concrete sewer required to carry a storm flow of ½ cu. ft. per second per acre from a drainage area of ½ square mile (= 320 acres), the grade being 0.3 per cent?

Answer. See *B*, above. 4 ft. 6 in. by 6 ft. 9 in.

Example 13. A 6-foot circular sewer and a 5 by 7 ft. 6-in. egg-shaped sewer have nearly the same area of cross-section. If both are laid to a 0.2 per cent grade, find the discharge and velocity of each when flowing full. (NOTE: Solve by Figs. 28 and 29. See *A*, above.)

Answer. Discharge, 165 cu. ft. per second; and velocity, 5.8 ft. per second, for the circular sewer; and discharge 163 cu. ft. per second; and velocity, 5.7 ft. per second, for the egg-shaped sewer.

NOTE: Although the egg-shaped sewer has a slightly smaller velocity when both are flowing full, it has a materially greater velocity than the circular sewer for small depths of flow.

Example 14. If the minimum allowable velocity of flow in storm sewers is 3 ft. per second, find the minimum allowable grades for 2 ft. by 3 ft., 4 ft. by 6 ft., and 6 ft. by 9 ft. egg-shaped sewers, respectively.

Answer. See *C*, above. 0.20, 0.08, and 0.05 per cent, respectively.

43. Diagram of Discharges and Velocities in Circular Sewers at Different Depths of Flow. The diagrams so far given show the discharges and velocities in sewers *flowing full.* It often, however, is necessary to be able to calculate the discharge and the velocity when the sewer flows only *partially* full.

For *circular sewers*, the discharges and velocities, when flowing only *partially full*, can readily be determined by the use of the diagram, Fig. 30, in connection with Figs. 27 and 28.

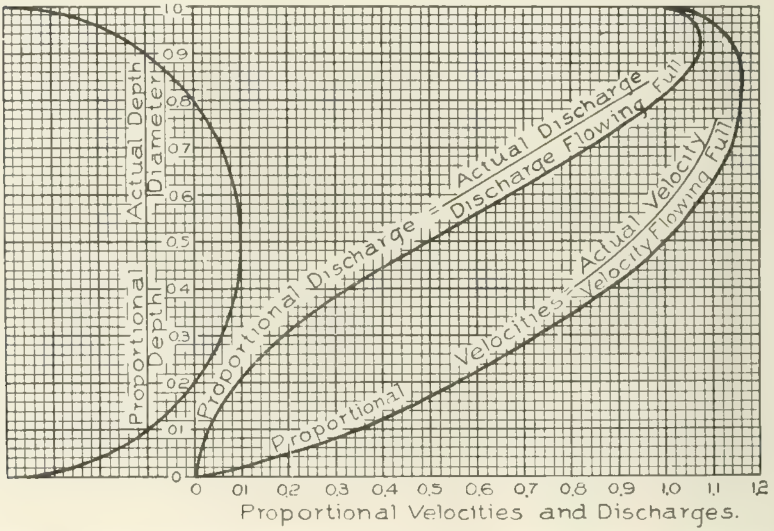


Fig. 30. Diagram Showing Changes in Velocity and Discharge in Circular Sewers for Different Depths of Flow.

TO USE THE DIAGRAM

(A) *When the depth of flow is given, together with the diameter and grade of the sewer, to determine the discharge and the velocity.*

(1) By Fig. 27 if a pipe sewer, or by Fig. 28 if a brick or concrete sewer, determine the *discharge* and *velocity* of the sewer *flowing full.* (2) Divide the given depth of flow by the given diameter, to determine the *proportional depth* of flow; and find this proportional depth on the vertical scale towards the left of Fig. 30, interpolating by the eye, if necessary. (3) Find the intersection of the horizontal line through the proportional depth (found in 2, above), first, with the *proportional discharge line,* and, second, with the *proportional velocity line,* in Fig. 30; and read off at the bottom of the diagram vertically below these intersection points, the *proportional discharge* and the *proportional velocity.* (4) Multiply the *discharge and velocity flowing full* (found in 1, above), by the *proportional discharge* and *proportional velocity*

found in 3, above), and the products will be the required *actual discharge and actual velocity, for the given depth of flow.*

(*B*) *When the actual discharge is given, together with the diameter and grade of the sewer, to find the depth and velocity of flow.*

(1) By Fig. 27 if a pipe sewer, or by Fig. 28 if a brick or concrete sewer, determine the *discharge of the sewer flowing full.* (2) Divide the given discharge by the discharge flowing full, to determine the *proportional discharge*; and find this along the bottom of the diagram in Fig. 30, interpolating by the eye, if necessary. (3) Find the intersection of the vertical line through the proportional discharge (found in 2, above) with the *proportional discharge curve* in Fig. 30; and horizontally to the left, read off on the vertical scale near the left of the diagram the *proportional depth* of flow. (4) Multiply the diameter of the sewer by the proportional depth, and the product will be the *actual depth of flow for the given discharge.* (5) The actual velocity can now be found as described above for case *A*.

All other cases than *A* and *B* can be readily solved by similar obvious methods.

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Example 15. What will be the actual discharge and velocity of flow in a 48-inch circular brick sewer laid to a 0.15 per cent. grade, and flowing 6 inches deep?

Solution. See *A*, above. (1) By Fig. 28, with the sewer flowing full, the discharge would be 30,000,000 gallons per day, and the velocity 3.8 ft. per second. (2) $\frac{6\text{ inches}}{48\text{ inches}} = 0.12 =$ proportional depth of flow, which we find on the vertical scale near the left of Fig. 30. (3) Horizontally opposite the point found in 2, we locate points on the proportional discharge curve and the proportional velocity curve in Fig. 30; and vertically beneath these points we read at the bottom of the diagram, 0.04 = proportional discharge, and 0.40 = proportional velocity. (4) $0.04 \times 30{,}000{,}000$ gallons = 1,200,000 gallons per day = actual discharge for 6 inches depth of flow; and $0.40 \times 3.8 = 1.5$ ft. per second = actual velocity for 6 inches depth of flow.

Example 16. An 8-inch pipe sewer, laid to a 0.40 per cent grade, is to carry the sewage of 500 people contributing 100 gallons each per day. What will be the average depth and velocity of flow?

Solution. See *B*, above. (1) By Fig. 27, the discharge and velocity flowing full would be respectively 450,000 gals. per day, and 1.9 ft. per second. (2) The actual discharge is $500 \times 100 = 50{,}000$ gals. per day, and hence the *proportional discharge* is $\frac{50{,}000}{450{,}000} = 0.11$. We find this proportional discharge along the bottom line of Fig. 30, interpolating by eye. (3) Vertically above the 0.11 proportional velocity, we find a point on the proportional discharge curve; and tracing horizontally to the left, we there read off the proportional depth = 0.225. (4) 0.225 × 8 = 1.8 inches = the actual depth of flow for the given discharge. (5) Horizontally to the right from the 0.225 proportional depth, we find a point on the proportional velocity line; and vertically beneath this point we read off at the bottom of the diagram, proportional velocity = 0.60. Then 0.60 × 1.9 (see 1, above) = 1.1 ft. per second = actual velocity for the given depth.

Example 17. What will be the discharge and velocity of a 12-inch pipe sewer laid to a 0.25 per cent grade when flowing 4 inches deep? See *A*, above.

Answer. Discharge, 250,000 gals. per day; velocity, 1.7 ft. per second.

Example 18. What will be the depth and velocity of flow in a 15-inch pipe sewer, laid at a 0.2 per cent grade, carrying 1,000,000 gallons of sewage per day?

See *B*, above.

Answer. Depth, 8 inches; velocity, 2.3 ft. per second.

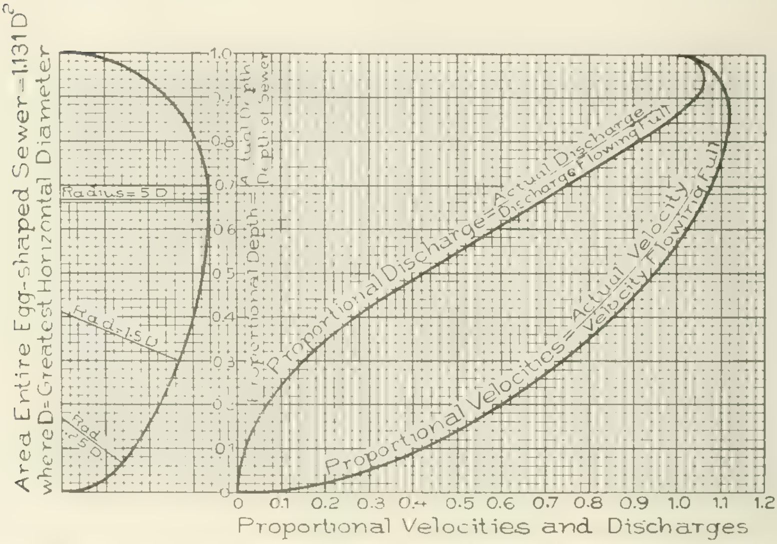

Fig. 31. Diagram Showing Changes in Velocity and Discharge in Egg-Shaped Sewers for Different Depths of Flow.

44. Diagram of Discharges and Velocities in Egg-Shaped Sewers at Different Depths of Flow. For egg-shaped sewers, the discharges and velocities, when flowing *partially full*, can readily be determined by the diagram, Fig. 31, used in connection with Fig. 29.

TO USE THE DIAGRAM

(*A*) *When the depth of flow is given, together with the diameter and grade of the sewer, to determine the discharge and the velocity.*

(1) By Fig. 29, determine the *discharge and velocity* of the sewer *flowing full.* (2) Divide the given depth of flow by the given height to determine the *proportional depth* of flow, and find this proportional depth on the vertical scale towards the left of Fig. 31, interpolating by the eye, if necessary. (3) Find the intersection of the horizontal line through the proportional depth (found in 2, above), first, with the *proportional discharge line,* and, second, with the *proportional velocity* line, in Fig. 31; and read off at the bottom of the diagram, vertically below these intersection points, the *proportional discharge,* and the *proportional velocity.* (4) Multiply the *discharge and velocity flowing full* (found in 1, above), by the *proportional discharge and proportional velocity* (found in 3, above), and the products will be the required *actual discharge and actual velocity for the given depth of flow.*

(*B*) *When the actual discharge is given, together with the diameter and grade of the sewer, to find the depth and velocity of flow.*

(1) By Fig. 29, determine the *discharge of the sewer flowing full.* (2) Divide the given discharge by the discharge flowing full, to determine the *proportional discharge,* and find this along the bottom of the diagram in Fig. 31, interpolating by the eye, if necessary. (3) Find the intersection of the vertical line through the proportional discharge (found in 2, above), with the *proportional discharge curve* in Fig. 31, and horizontally to the left, read off on the vertical scale near the left of the diagram the *proportional depth* of flow. (4) Multiply the height of the sewer by the proportional depth, and the product will be the *actual depth of flow for the given discharge.* (5) The actual velocity can now be found as described above for case *A*.

All other cases than *A* and *B* can be readily solved by similar obvious methods.

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Example 19. What will be the discharge and velocity in an egg-shaped brick or concrete sewer 3 ft. by 4 ft. 6 in., laid to a 0.15 per cent grade, and flowing 12 inches deep?

See *A*, above.

Solution. (1) By Fig. 29, discharge and velocity flowing full = 36 cu. ft. per second, and 3.45 ft. per second, respectively. (2) The proportional depth $= \frac{12}{54} = 0.22$, which we find at left of Fig. 31. (3) We locate the intersections of the horizontal line through the 0.22 proportional depth with the proportional discharge and proportional velocity curves, respectively; and vertically below these points we read off, at the bottom of the diagram, proportional discharge = 0.08, and proportional velocity = 0.63. (4) $36 \times 0.08 = 2.9$ cu. ft. per second = actual discharge; $3.45 \times 0.63 = 2.2$ ft. per second = actual velocity.

Answer. Discharge = 2.9 cu. ft. per second; velocity = 2.2 ft. per second.

Example 20. What will be the depth and velocity of flow in an egg-shaped brick or concrete sewer 5 ft. by 7 ft. 6 in. dimensions, laid to a 0.40 per cent grade, and carrying 30 cu. ft. per second flow of sewage?

See *B*, above.

Solution. (1) By Fig. 29, the discharge and velocity flowing full = 117 cu. ft. per second and 4.05 ft. per second, respectively. (2) Proportional discharge = $\frac{30}{117}$ = 0.26–, which find at bottom of Fig. 31. (3) Vertically above the 0.26 proportional discharge, we locate a point on the proportional discharge curve in Fig. 31, and horizontally to the left from this point read off the proportional depth = 0.39. (4) 90 × 0.39 = 35 inches = actual depth of flow. (5) Horizontally to the right along the 0.39 proportional depth line, we locate a point on the proportional velocity line; and vertically beneath this, we read off, at the bottom of the diagram, proportional velocity = 0.845. Then 4.05 × 0.845 = 3.4 ft. per second = actual velocity.

Answer. Depth of flow = 35 inches; velocity = 3.4 ft. per second.

Example 21. What will be the discharge and velocity in an egg-shaped brick or concrete sewer 2 ft. by 3 ft. dimensions, laid to a 0.50 per cent grade, flowing 18 inches deep?

See *A*, above.

Answer. Discharge = 5,900,000 gals. per day; velocity = 4.5 ft. per second.

Example 22. What will be the depth and velocity of flow in an egg-shaped brick or concrete sewer 3 ft. 6 in. by 5 ft. 3 in. dimensions, laid to a 0.08 per cent grade, carrying 25 cu. ft. per second of sewage?

See *B*, above.

Answer. Depth of flow = 39 inches; velocity of flow = 2.9 ft. per second.

GENERAL EXAMPLES FOR PRACTICE WITH FIGS. 27-31

45. The solution of the following general examples will further familiarize the student with the principles thus far explained.

Example 23. A 24-inch sewer is to be laid to a 0.25 per cent grade, and may be made of vitrified sewer pipe or of brick. Compare the discharges and velocities obtained with the two materials. (NOTE: Use Figs. 27 and 28.)

Answer. With sewer pipe, discharge = 7,200,000 gals. per day; velocity = 3.6 ft. per second.
With brick, discharge = 6,000,000 gals. per day; velocity = 3 ft. per second.

Example 24. A combined sewer, laid to a 0.15 per cent grade, drains an area requiring either a 3-foot circular or a 2 ft. 6 in. by 3 ft. 9 in. egg-shaped brick sewer. (These sizes have the same cross-sectional area, and nearly the same discharges and velocities, when flowing full.) The dry-weather flow of sewage will be only 1,000,000 gallons per day. Calculate the dry-weather depth and velocity of flow with each design. (NOTE: Use Figs. 28 and 30, and Figs. 29 and 31.)

Answer. With circular sewer, depth = 6.1 inches; velocity = 1.6 ft. per second.

With egg-shaped sewer, depth = 9.2 inches; velocity = 1.9 ft. per second.

Example 25. In a 10-inch pipe sewer, laid to a one per cent grade, the maximum depth of flow observed was 7 inches; and the minimum, 2 inches. What were the corresponding discharges? (NOTE: Use Figs. 27 and 30.)

Answer. Maximum discharge = 1,100,000 gals. per day;
Minimum " = 120,000 " " "

Example 26. What size of circular sewer laid to a 0.08 per cent grade will be required to carry the sanitary sewage of a city of 100,000 population, with an average flow of sewage of 150 gallons per capita per day, the maximum rate of flow being three times the average?

Answer. 5 ft. 3 in. diameter.

Example 27. What size of egg-shaped combined sewer, laid to a 0.07 per cent grade will be required to carry a storm sewage flow of 0.5 cu. ft. per second per acre from a drainage area of 320 acres?

Answer. 6 ft. by 9 ft.

46. Summary of Laws of Flow in Sewers. The principles discussed in Articles 38 to 44, inclusive, may be briefly summarized as follows:

(1) The laws of flow for sewage are the same as for water.

(2) Kutter's formula is generally considered most reliable for calculating the flow in sewers, though complicated to use directly.

(3) In Kutter's formula, the values of the coefficient of roughness generally used for sewer computations, are $n = 0.013$ for pipe sewers, and $n = 0.015$ for brick and concrete sewers.

(4) Sewer diagrams greatly simplify sewer computations, and are presented in Figs. 27 to 31, inclusive, for circular and egg-shaped sewers, with full instructions for use.

(5) In Fig. 30, the laws of flow for different depths of flow in

circular sewers are shown. An examination of the diagram brings out this important law:

In circular sewers flowing half-full, the velocity is the same as when the sewer flows full; and hence the discharge flowing half-full is just half the discharge flowing full.

(6) Figs. 30 and 31 also show the following important law of flow:

In a sewer of any shape, not flowing under pressure, the maximum discharge and velocity will occur, not with the sewer flowing full, but with it flowing a little less than full.

This is due to the increased friction against the top of the sewer when it flows full. Owing to this law, no sewer can flow full without being under pressure.

(7) In the case of combined sewers having a dry-weather flow very small as compared with the storm flow, egg-shaped sewers give materially greater depths and velocities of dry-weather flow than circular sewers.

CALCULATIONS OF SIZES AND MINIMUM GRADES OF SEPARATE SANITARY SEWERS

47. Minimum Sizes of Sanitary Sewers. In the early construction of sewers, previous to the last half of the 19th century, the laterals and sub-mains were usually made very much larger than the amount of sewage would require, with the idea, apparently, that the bigger the sewer the better. Such badly proportioned sewers were in great danger of stoppages from the inability of the shallow, trickling stream to carry along the solid matter. In fact, the sewers were expected to form deposits, and were purposely made large to hold a large amount of deposit and to enable men to enter for the purpose of cleaning them. Disastrous sanitary experience with such foul sewers made it apparent that there was just as much danger from making the sewers too large as from making them too small, especially in the case of sanitary sewers. Such sewers should be made small enough to give a good depth and velocity of flow.

Sanitary sewers should not be made small enough, however, to cause frequent stoppages by catching articles which have been admitted into them through the house connections. House owners are often reprehensibly negligent in putting into their plumbing fixtures, articles which should be carefully excluded. On this account, the size of house connections should be restricted to 4 inches.

An 8-inch sewer pipe will practically always carry freely, even crosswise, any article which can come lengthwise around the traps and bends in 4-inch soil-pipes and house connections Hence *eight inches should usually be adopted as the minimum size for sanitary sewers.*

Usually the great bulk of the sanitary sewers in a separate system will be of this minimum size, only a limited length of the larger sizes being required for sub-mains and mains. See the sewerage map of Ames, Iowa, Fig. 38.

In the early use of the separate system, many 6-inch laterals were constructed, and, except for occasional stoppages from articles improperly put into the sewers, they have worked well. Some engineers still use six inches as the minimum size.

48. Minimum Grades and Velocities for Separate Sanitary Sewers. In the design and construction of sewers it has been found that certain minimum grades should be adopted to prevent deposits, no sewers being built to lighter grades than the minimum unless special means for flushing, or special facilities for cleaning, are provided. This is to insure sufficient velocity to prevent the settling-out of the solid matter in the sewage to form deposits in the sewers.

These minimum grades for separate sanitary sewers are as follows:

TABLE II
Minimum Grades for Separate Sanitary Pipe Sewers

DIAMETER	MINIMUM GRADE	DIAMETER	MINIMUM GRADE
4 inches	1.20 per cent	18 inches	0.12 per cent
6 "	0.67 " "	20 "	0.10 " "
8 "	0.43 " "	24 "	0.08 " "
9 "	0.36 " "	27 "	0.07 " "
10 "	0.30 " "	30 "	0.06 " "
12 "	0.23 " "	33 "	0.05 " "
15 "	0.16 " "	36 "	0.045 " "

CAUTION.—*For the above minimum grades to be satisfactory and safe, there must be enough sewage to give a good depth of flow.*

The flow and velocity in a sewer fluctuate greatly, as illustrated in Article 52, below, the velocity at low flow being much less than when flowing full or half-full.

Experiments have shown that an actual velocity of 1¼ to 1½ feet per second is sufficient to prevent deposits of the solid matters usually found in sanitary sewers; but to secure this velocity at low flow requires about 2 feet per second when the sewer flows full or half-full (see Figs. 30 and 31 for the fluctuation of velocity with depth of flow). Hence *the minimum grades for sanitary sewers should usually be those giving a velocity of 2 feet per second when flowing full or half-full, as shown by the diagrams, Figs.* 27, 28, *and* 29.

It is usually considered that, within a reasonable period in the future, the increased high-water flow each day should be sufficient to fill the sewer half-full or nearly so. However, in numerous cases, sanitary sewers have been observed to work well at the above grades with less depths of flow than this.

Much will depend on the nature of the sewage. Some thick, manufacturing sewages, heavily loaded with solid matter, would require considerably heavier grades to insure self-cleansing.

Where it is absolutely impossible to secure the above minimum grades, special means for flushing, such as automatic flush-tanks placed about three blocks apart, should be used.

49. General Explanation of the Calculation of Amount of Sanitary Sewage. The first thing necessary in computing the size required for any particular sanitary sewer, is to ascertain the amount of sewage it must carry. While this cannot be foretold with exactness, yet, by well-established methods, an approximation sufficiently close for all practical purposes can readily be made.

The *first step* in computing the amount of sewage will be to estimate the future tributary population which may use the sewer. For this, see Art. 50, below.

The *second step* will be to estimate the average amount of sewage contributed by each person per day—that is, the average flow of sewage per capita per day. This, multiplied by the tributary population, will give the total average amount of sewage per day which the sewer must carry.

Two methods are in use for estimating the average flow of sewage per capita per day:

(1) It is often assumed to equal the average consumption of water per capita per day. For this method, see Art. 51, below.

(2) The best method is to compare the local conditions with

actual sewer gaugings of flow in sewers under similar conditions elsewhere. For this method, see Art. 52, below.

50. Methods of Estimating the Population Tributary to Sanitary Sewers. The most important difficulty encountered in estimating the population tributary to sanitary sewers, is the fact that it is the *future* population which must be determined. To know the present tributary population is not sufficient. Two methods will be described:

(1) *The best method of estimating the future population tributary to sanitary sewers is as follows:*

(*a*) On the sewer map, lay out sewers to serve all districts to be served in the future as well as at present.

(*b*) After careful examination of the ground, and study of the conditions, estimate the number of persons tributary to the sewers per 100 feet of sewers in each district when it is built up as fully as can reasonably be expected.

In doing this, five or six persons per family should usually be allowed, and the number of families on both sides of the street for one block in the future estimated. The number of persons per block so obtained should then be divided by the number of hundred feet of sewer per block from center to center of streets.

Thus, if there are 6 lots 50 feet wide per block (=300 feet) on each side of the sewer, and the streets are 60 feet wide (=360 feet center to center of streets), and if it is thought that every lot will eventually contain one residence,

$$\text{Tributary population} = \frac{12 \times 6 \text{ persons}}{3.60} = 20 \text{ persons per 100 feet of sewer.}$$

The tributary population per 100 feet of sewer will usually range from 20 persons in the residence districts of small cities, to 100 persons in thickly built-up business districts. In the congested districts of the largest cities, the population is still denser.

(*c*) *To determine the total population tributary above any point on a sanitary sewer, scale from the sewer map the total number of hundred feet of tributary sewer above that point, including all branches; and multiply the total so obtained by the tributary population per* 100 *feet of sewer.*

Thus, if there are 15,600 ft. of tributary sewers, and the tributary population is 20 per 100 ft., the total tributary population will = 156 × 20 = 3,120 persons. In some cases part of the length of tributary sewers may have to be multiplied by one density of tributary population, and part by another.

(2) In case the future population of an entire city is to be estimated, a different method must be used.

Usually, the past population of the city at different dates is obtained from census reports; and by study of this past growth, and of the present and probable future local conditions as affecting growth, and by comparison with the past growth of larger cities whose conditions were similar, estimates are made of the probable future populations at different dates, for 20 to 50 years in the future.

Usually, also, the past records of the city that is being studied, and of others, are platted as curves on cross-section paper, the ordinates representing population, and the abscissæ dates; and the future estimates are made by prolonging the curve of growth into the future.

51. Use of Statistics of Water Consumption in Determining the Per Capita Flow of Sanitary Sewage. Since about 99.8 per cent of sanitary sewage is merely ordinary water, nearly always taken from the public supply, the total flow per capita of sanitary sewage is usually approximately equal to the consumption of water per capita (that is, per person). In Fig. 32 may be seen how closely sewage flow and water consumption ordinarily correspond.

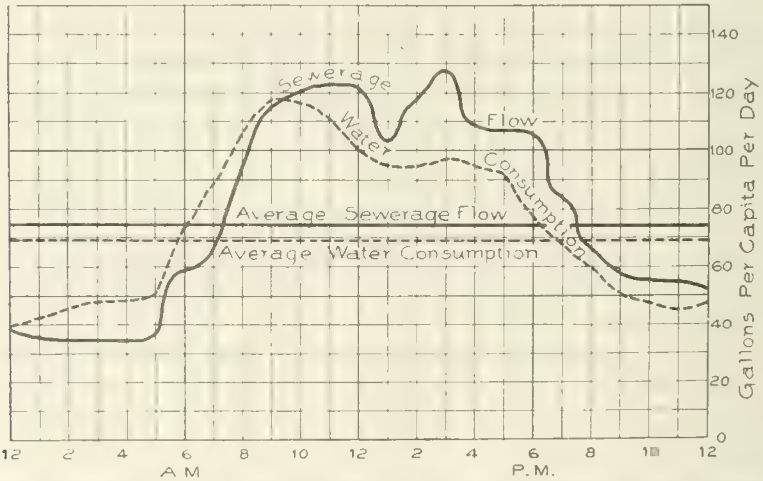


Fig. 32. Typical Gauging of Flow of Sanitary Sewage, Des Moines, Iowa, Friday, July 5, 1895.

In many towns, however, there will not be such close correspondence. Sometimes considerable amounts of water may be used for manufacturing or other purposes which divert it from the sewers, making the sewage flow less than the water consumption. More often there will be considerable influxes of ground water through leaking sewer joints, sometimes making the sewage flow several times as great as the water consumption.

However, very extensive statistics of water consumption in a large number of places have been collected, while actual gaugings of flow of sewage are comparatively few. Hence statistics of the water consumption of the town for which sewers are being designed, or of similar towns elsewhere, are often used as the basis for estimating the per capita flow of sanitary sewage. In studying each town preliminary to designing sewers for it, all possible information should be secured relative to its water consumption.

TABLE III

Consumption of Water in American Cities, 1895

CITY	POPULATION	DAILY CONSUMPTION PER PERSON, 1895. GALLONS
New York	3,437,202	100
Chicago	1,698,575	139
Philadelphia	1,293,697	162
St. Louis	575,238	98
Boston	560,892	100
San Francisco	342,782	63
Buffalo	352,387	271
New Orleans	287,104	35
Minneapolis	202,718	88
Columbus	125,560	127
Atlanta	89,872	42
Nashville	80,865	139

On pages 4 to 10 of the instruction paper on Water Supply, Part I, will be found a detailed discussion of water consumption. From a larger table given there, Table III herewith is condensed, to show how the average per capita water consumption varies in different American cities.

It will be noted that there is a very wide range in water consumption. The excessively low rates usually mean an incomplete water supply, which is likely to be extended later, while the excessively high rates usually mean great waste of water. This can often be greatly reduced by introducing water meters.

Under fairly average conditions the consumption will usually fall between the limits of 40 and 125 gallons per capita per day, as shown in detail in Table IV.

TABLE IV

Water Consumption under Ordinary Conditions

Use	Gallons per Capita per Day		
	Minimum	Average	Maximum
Domestic	15	25	40
Commercial	7	20	35
Public	3	5	10
Waste and Loss	15	25	40
Total	40	75	125

52. Use of Sewer Gaugings in Determining the Per Capita Flow of Sanitary Sewage. It has already been stated that the flow of sanitary sewage is not always equal to the water consumption. In one case of sewer gaugings, the writer found the flow of sewage to be only 50 to 60 per cent of the water consumption, the remainder of the water being consumed for purposes which diverted it from the sewers. In another case of sewer gaugings, the writer found the flow of sewage to be over 500 per cent of the water consumption, the increase being due to infiltration of ground water through sewage joints. Hence, water consumption data alone are not sufficient in making estimates of sewage flow, and data from actual sewer gaugings are needed. Of late years there is an increasing accumulation of data of sewage flow obtained from actual gaugings. Some of these data are given in Table V.

At the Iowa State College, the sewage flow, as given in Table V, below, was 50 to 60 per cent of the water consumption, owing to uses of water which diverted it from the sewers. At Grinnell, on the other hand, infiltration of ground water into the sewers increased the sewage flow to about six times the total water consumption on the same day.

A study of Table V will show, however, that *in general the average flow of sanitary sewage is between the limits of 50 and 125 gallons per capita per day.*

53. Capacities of Sanitary Sewers Required to Provide for Fluctuations in the Rate of Flow. So far our discussion of flow of

TABLE V

Gaugings of Flow of Sanitary Sewage

Sewer	Date	Duration, Days	Tributary Population	Sewage Flow, Gals. per Capita per Day		
				Min	Av.	Max
Compton Ave., St. Louis	1880	6	8,200	65	102	149
College St., Burlington, Vt.	1880	5–8	325	65	115	140
Huron St., Milwaukee, Wis.	1880	–	3,174	– –	– –	120
Memphis, Tenn.	1881	–	20,000	61	–	140
13 Sewers, Providence, R. I.	1884	1–6	33,825	–	78	—
Asylum, Binghamton, N. Y.	1888	–	1,300	– –	–	608
16 Sewers, Toronto, Ont.	1891	3	168,081	– –	87	——
Insane Asylum, Weston, W. Va.	1891	2	1,000	40	91	151
Schenectady, N. Y.	1892	1	*10,000	72	86	103
Canton, Ohio	1893	-	40,000	54	129	180
Chautauqua, N. Y.	1894		7,000	6	20	30
Iowa State College, Ames, Ia.	1894	7	289	0	32	77
Des Moines, Ia., E. Side	1895	15	8,100	22.5	74	142
Des Moines, Ia., W. Side	1895	13	19,400	23.2	66	175.3
Iowa State College, Ames, Ia.	1900	2	800	54	95	175
Iowa State College, Ames, Ia.	1900	28	800	30	57	130
Marshalltown, Ia.	1900	1	4,200	67	85	111
Grinnell, Ia.	1901	1	2,000	169	186	200
Insane Asylum, Mt. Pleasant, Ia.	1901	1	1,200	32	62	115
Waverly, N. Y.	1905	1	1,796	79	155	194

* Estimated.

sanitary sewage (Arts. 51 and 52) has referred particularly to the *average* flow per capita per day. The flow, however, is not uniform, but fluctuates greatly. First, there is a *seasonal fluctuation*. The flow is apt to be especially high in severe cold weather, when faucets are left running to keep pipes from freezing; in hot weather, when water consumption is high; and in wet weather, when some ground water finds its way into the sewers.

Second, there is a *daily fluctuation*. For example, gaugings show that the flow usually is light on Sundays and holidays, when business is suspended. The flow on Monday is apt to be especially high, on account of wash day.

Third, there is an *hourly fluctuation*, at different times of the day and night. In Fig. 32, an example is shown of the fluctuation of sewage flow throughout one day, as determined by a continuous sewer gauging in the case of a city of 56,000 population. As shown in this figure, the flow of sanitary sewage is usually low through the night, reaching a minimum at about 2 to 3 A. M. It increases rapidly early in the morning, reaching a high point at about 10 to 11 A. M. Although there is usually a temporary drop at the noon hour, the flow continues high until early evening, and then decreases rapidly to its low night value.

A study of the sewer gaugings summarized in Table IV, together with others, shows that the flow of sanitary sewage ordinarily fluctuates from a minimum rate of 30 per cent to a maximum rate of 265 per cent of the average rate. If the gaugings had been extended over longer periods of time, still greater fluctuations of flow would certainly have been found.

It is apparent that the fluctuations in rate of flow will be greater in lateral sewers than in main sewers. To make them large enough to provide for the greatest rates of flow to be reasonably expected, *sanitary sewers should be given the following capacities*:

PROPER CAPACITIES OF SANITARY SEWERS

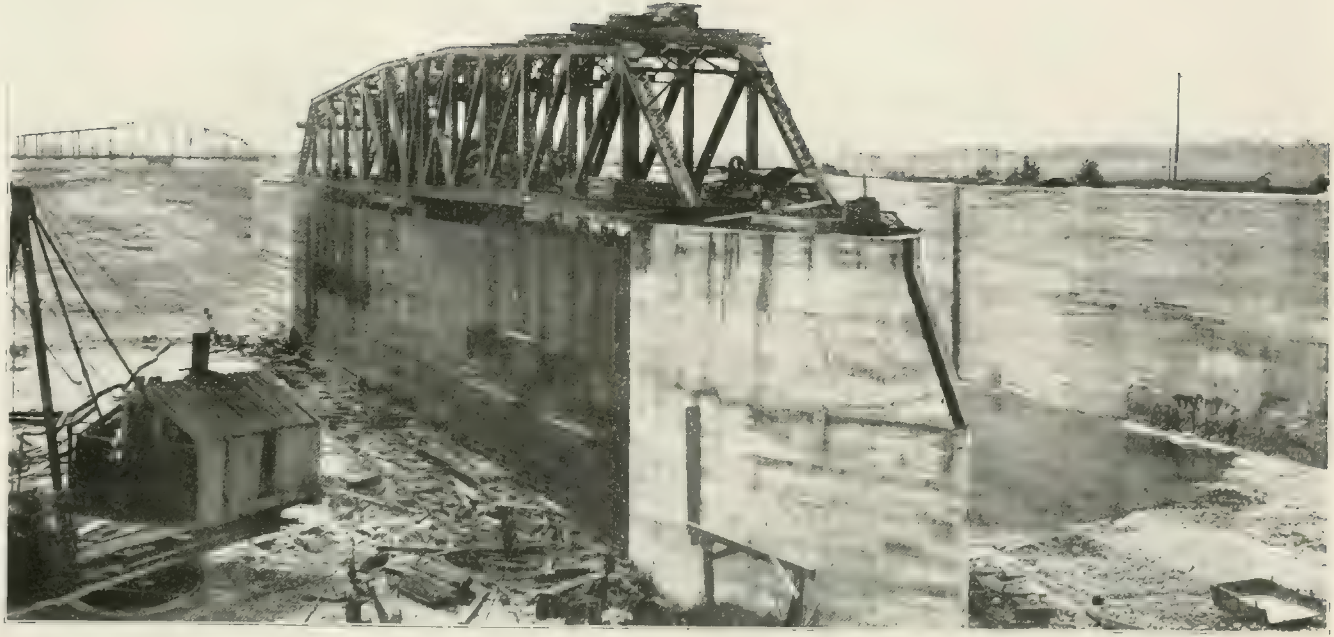
For lateral sewers, 350 per cent of the average flow.
For sub-main sewers, 325 per cent of the average flow.
For main sewers, 300 per cent of the average flow.

Table VI (page 68) is proportioned on the above basis.

54. Ground Water in Sanitary Sewers. In addition to the sanitary sewage itself, provision must often be made in separate sanitary sewers for leakage of ground water into the sewers. The amount of ground water to be allowed for, will depend on the character of the soil, on the height of the ground water with reference to the sewer, and on the care with which the sewer joints are made. *If the joints are made very carefully, the amount of ground water to be expected may range, with the soil, and height of ground water, from 0 to 30,000 gallons per mile.* This will constitute, say, 0 to 30 per cent of the sewage, but is a steady flow, not requiring the 300 to 350 per cent allowance for fluctuations required for sewage (see Art. 53). Hence, *if the joints are carefully made, the capacity of the sewers need not be increased more than 10 per cent for ground water.*

If sub-drains with outlets separate from the sewers are provided for all wet stretches of trench, no allowance whatever for ground water need be made in the size of the sewers.

The infiltration of ground water is apt to be much greater during and immediately after the construction of sewers than later, for the effect of sewers is to lower permanently the level of the ground water.



"BUTTERFLY" DAM, CHICAGO DRAINAGE CANAL, LOCKPORT, ILL.

Ordinarily the dam is open, the movable leaf, shown under the bridge, pointing up and down stream. This leaf swings on a central pivot and, when once started by rack and pinion throwing it into the current, swings across the channel, closing it automatically, the small gates in one arm of the leaf being closed while those in the other arm are left open, thus varying the pressure on the two arms. The leaf may be swung back automatically by simply reversing the operation of the small gates, closing those that were before open, and *vice versâ*.

Isham Randolph, Chief Engineer.

55. Summary of Methods of Computing Sizes of Separate Sanitary Sewers. The methods for computing the sizes of sanitary sewers may be summarized as follows:

(1) Lay out on the sewer map all the sewers required to serve all districts which can reasonably be expected to be included in the system, either at present or within say 30 to 50 years in the future.

(2) By a careful study of the topography, business conditions, manufacturing possibilities, and other future prospects, together with the sizes of blocks and lots, and the widths of streets, determine the probable future tributary population in each district per 100 feet of sewer, allowing usually five or six persons per family.

(3) By a careful study of the statistics of water consumption (Art. 51), and by comparison with actual sewer gaugings (Art. 52), taking into account all local conditions, estimate the average flow of sewage in gallons per capita per day.

(4) Beginning at the upper ends of the sewers, scale from the map and tabulate the total lengths of tributary sewer above successive points in the system, to the outlet. Multiply the number of hundreds of feet in these lengths by the tributary population per 100 feet, and by the average per capita flow of sewage per day, to get the total flow of sanitary sewage at the successive points.

(5) To allow for fluctuations (Art. 53), multiply the above average rates of flow of sanitary sewage by

3½ for lateral sewers;
3¼ " sub-main "
3 " main "

to get the maximum rates of flow of sanitary sewage.

(6) To the maximum rates of flow so found, add 0 to 30,000 gallons per mile of tributary sewers, to allow for ground water (Art. 54).

(7) Occasionally it may be necessary also, in the case of certain sewers, to make special allowances for manufacturing sewage from large factories, each factory being studied by itself to determine its probable sewage flow. This flow will usually be subject to as much fluctuation as sanitary sewage, and hence must be multiplied by the factors given in 5, above.

(8) On the sewer profiles (see Art. 92), the grades of the sewers at the successive points will be determined and shown. Using these grades, and the total maximum rates of flow of sewage determined

TABLE VI
Sizes Required for Separate Sanitary Pipe Sewers

1	2	3	4	5	6	7	8	9
Diam. of Sewer, Ins.	Grade of Sewer	Maximum Permissible Av. Flow, Gals. per Day	Maximum Permissible Tributary Population			Maximum Permissible Linear Feet of Tributary Sewer for 20 Persons per 100 Feet		
			Gals. per Capita per Day			Gals. per Capita per Day		
			75	100	125	75	100	125
8	0.45	130,000	1,700	1,300	1,000	8,700	6,500	5,200
	0.60	160,000	2,100	1,600	1,300	11,000	8,000	6,400
	0.80	180,000	2,400	1,800	1,400	12,000	9,000	7,200
	1.00	200,000	2,700	2,000	1,600	13,000	10,000	8,000
	1.40	240,000	3,200	2,400	1,900	16,000	12,000	9,600
10	0.20	220,000	2,900	2,200	1,800	15,000	11,000	8,800
	0.40	260,000	3,400	2,600	2,100	17,000	13,000	10,000
	0.60	310,000	4,100	3,100	2,500	21,000	15,000	12,000
	0.80	360,000	4,800	3,600	2,900	24,000	18,000	14,000
	1.00	400,000	5,300	4,000	3,200	27,000	20,000	16,000
12	0.23	350,000	4,700	3,500	2,800	23,000	17,000	14,000
	0.40	460,000	6,100	4,600	3,700	31,000	23,000	18,000
	0.60	560,000	7,500	5,600	4,500	37,000	28,000	22,000
	0.80	650,000	8,700	6,500	5,200	43,000	32,000	26,000
	1.00	720,000	9,600	7,200	5,800	48,000	36,000	29,000
15	0.17	550,000	7,300	5,500	4,400	37,000	27,000	22,000
	0.30	750,000	10,000	7,500	6,000	50,000	37,000	30,000
	0.40	850,000	11,000	8,600	6,900	57,000	43,000	34,000
	0.60	1,000,000	13,000	10,000	8,000	67,000	50,000	40,000
	0.80	1,200,000	16,000	12,000	9,600	80,000	60,000	48,000
18	0.13	800,000	11,000	8,000	6,400	55,000	40,000	32,000
	0.30	1,200,000	16,000	12,000	9,600	80,000	60,000	48,000
	0.40	1,400,000	19,000	14,000	11,000	93,000	70,000	56,000
	0.60	1,700,000	23,000	17,000	14,000	113,000	85,000	68,000
	0.80	2,000,000	27,000	20,000	16,000	134,000	100,000	80,000
24	0.10	950,000	12,000	9,500	7,400	62,000	46,000	37,000
	0.20	1,300,000	17,000	13,000	10,000	87,000	65,000	52,000
	0.40	1,900,000	25,000	19,000	15,000	126,000	95,000	76,000
	0.60	2,300,000	31,000	23,000	18,000	153,000	115,000	92,000
	0.80	2,600,000	35,000	26,000	21,000	173,000	130,000	104,000
27	0.08	1,400,000	19,000	14,000	11,000	93,000	70,000	56,000
	0.20	2,200,000	29,000	22,000	18,000	147,000	110,000	88,000
	0.30	2,700,000	36,000	27,000	22,000	180,000	135,000	108,000
	0.40	3,100,000	41,000	31,000	25,000	207,000	155,000	124,000
	0.60	3,800,000	51,000	38,000	30,000	254,000	190,000	152,000
30	0.06	2,200,000	29,000	22,000	18,000	147,000	110,000	88,000
	0.10	2,800,000	37,000	28,000	22,000	187,000	140,000	112,000
	0.20	4,000,000	53,000	40,000	32,000	267,000	200,000	160,000
	0.40	5,700,000	76,000	57,000	46,000	380,000	285,000	238,000
	0.60	7,000,000	93,000	70,000	56,000	466,000	350,000	280,000
36	0.05	3,200,000	43,000	32,000	26,000	214,000	160,000	128,000
	0.10	4,600,000	61,000	46,000	37,000	307,000	230,000	184,000
	0.20	6,500,000	87,000	65,000	52,000	433,000	325,000	260,000
	0.40	9,300,000	124,000	93,000	74,000	620,000	465,000	372,000
	0.60	11,400,000	152,000	114,000	91,000	760,000	570,000	456,000

in 5, 6, and 7, above, refer to Fig. 27 for pipe sewers, or to Fig. 28 for brick or concrete sewers, and find the sizes of sewers required.

Example 28. In a town in which the blocks are 340 feet, center to center of streets, there are 14 lots per block. The total length of tributary sewers above a certain point on a sub-main sewer in the system (separate sewers), is 16,600. The conditions affecting rate of sewage flow per capita are average. No allowance need be made for ground water or manufacturing sewage. The grade of the sewer is 0.30 per cent. What size is required?

Solution. The tributary population will be $\frac{14 \times 6}{3.4} = 25$ persons per 100 feet of sewer. The average rate of flow may be assumed at 85 gallons per capita per day. Hence the maximum rate of flow for this sub-main sewer will be $166 \times 25 \times 85 \times 3\frac{1}{4} = 1,150,000$ gallons per day.

Hence, by Fig. 27, for a 0.30 per cent grade, a 12-inch pipe sewer will be required.

Answer. A 12-inch pipe sewer.

56. Table of Sizes Required for Sanitary Sewers. By the methods given in Art. 55, omitting allowances for ground water and manufacturing sewage, Table VI (page 68) has been computed, to reduce the labor of computation of sizes of separate sanitary pipe sewers.

TO USE THE TABLE

Proceed to follow out steps 1, 2, 3, and 4, in Art. 55, just above (which read), thus determining the total estimated future number of linear feet of tributary sewer at successive points, the estimated future number of persons tributary per 100 feet of sewer (which let $= P$), and the estimated average flow of sewage in gallons per capita per day (which let $= F$). Also ascertain the grade to which the sewer is to be built.

(*A*) *If $P = 20$ persons per 100 feet, and if F lies between 75 and 125 gallons per capita per day, and if no allowance is necessary for ground water or manufacturing sewage,* find in column 7, 8, or 9, or by interpolating between them, according to the value of F, a number close to the calculated number of linear feet of tributary sewer opposite to the given sewer grade, interpolating between the grades, and take the corresponding size of sewer in column 1.

Example 29. For 13,100 linear feet of sewer, 20 persons per 100 ft., 85 gallons per capita per day, and 0.35 per cent grade.

We find that for a 0.35 per cent grade an 8-inch sewer would be considerably too small, as shown by interpolating between the numbers in columns 7 and 8, while a 10-inch sewer would be a little larger than needed.

Answer. A 10-inch pipe sewer.

(*B*) If P does not $= 20$ persons per 100 feet (the other conditions remaining as in *A*, above), first multiply the number of linear feet of tributary sewer by $\frac{P}{20}$, and then proceed as in *A*, just above.

Example 30. For 16,300 linear feet of sewer, 30 persons per 100 feet of sewer, 110 gallons per capita per day, and a sewer grade of 0.25 per cent.

We first find $16,300 \times \frac{30}{20} = 24,450$ linear feet. Then interpolating between columns 8 and 9, we find that for a 0.25 per cent grade a 12-inch would be considerably too small, while a 15-inch sewer is a little larger than needed.

Answer. A 15-inch pipe sewer.

(*C*) If F (= rate of sewage flow) is less than 75 or more than 125 gallons per capita per day, first multiply the number of linear feet of tributary sewer by $\frac{F}{100}$, and then by $\frac{P}{20}$ (where P = persons per 100 feet of sewer), and then find the nearest number in column 8 opposite the given grade.

Example 31. For 22,500 linear feet of sewer, 35 persons per 100 feet, 150 gallons per capita per day, and 0.45 per cent grade.

We first find $22,500 \times \frac{150}{100} \times \frac{35}{20} = 59,000$ linear feet. In column 8 we find that for a 0.45 per cent grade a 15-inch sewer would be considerably too small, while an 18-inch is too large.

Answer. An 18-inch pipe sewer.

(*D*) *If ground water or manufacturing sewage, or both,* must be allowed for, ascertain the *total average sewage flow,* by multiplying the linear feet of tributary sewer by $\frac{P}{100}$ (P = persons per 100 feet), and this result by F (= gallons per capita per day, of sanitary sewage), and by then adding to this result the total allowance for manufacturing sewage, and ⅓ the total allowance for ground water. Then find by interpolation in column 3 the nearest number opposite the given grade, and take the corresponding size of sewer.

Example 32. For 15,600 linear feet of tributary sewer, 25 persons per 100 feet, 85 gallons per capita per day, 15,000 gallons per day per mile ground water, 200,000 gallons per day manufacturing sewage, and 0.20 per cent grade.

We find the total average flow of sewage to use is $15,600 \times \frac{25}{100} \times 85 + 200,000 + \frac{15,000}{3} \times 3$ (miles) $= 546,000$ gallons per day. In column 3 we find that for a 0.20 per cent grade, a 12-inch sewer would be considerably too small, while a 15-inch is a little larger than is needed.

Answer. A 15-inch pipe sewer.

GENERAL EXAMPLE FOR PRACTICE IN DESIGNING SEPARATE SANITARY SEWERS

57. Working out the following example will materially help the student.

Example 33. Calculate the size of the outlet sewer of the sewer system shown in Fig. 4, assuming that there will be in the future 20 persons tributary per 100 feet of sewer, that the average flow of sewage will be 100 gallons per capita per day, no special allowance for ground water or manufacturing sewage being needed. Also assume that there may be in the future 15,000 feet of sewer extensions not shown in the figure. The grade of the outlet sewer is 0.20 per cent. Assume scale of drawing, 1,500 feet per inch.

Solution. Take a long strip of paper with one edge straight; and on this, mark off with a pencil a scale of feet from the scale assumed above. With this, scale off the lengths of all the sewers shown, except the storm sewers. Add up the lengths scaled, and add 15,000 linear feet of future extensions, to get the total length of tributary sewer. Then use Table VI.

Answer. An 18-inch pipe sewer.

CALCULATION OF SIZES AND MINIMUM GRADES OF STORM AND COMBINED SEWERS

58. Storm and Combined Sewers Calculated by Same Methods. In combined sewers the rate of flow of sanitary sewage is so small in time of storms in proportion to that of the storm sewage, that the sanitary sewage can be neglected altogether in calculating the size. For example, a combined sewer one mile long, with 20 persons tributary per 100 feet, and 75 gallons per capita per day, would have a maximum rate of flow of sanitary sewage at its lower end of $\frac{52.8 \times 20 \times 75 \times 3\frac{1}{2}}{7\frac{1}{2} \times 86{,}400} = 0.43$ cu. ft. per second (there being $7\frac{1}{2}$ gals. in 1 cu. ft., and 86,400 seconds in 1 day, and the maximum rate of flow being $3\frac{1}{2}$ times the average).

If the blocks are 360 feet wide, center to center of streets, this same sewer would have to take the storm sewage from $43\frac{1}{2}$ acres. The amount of this at the time of the maximum storm allowed for, calculated by the methods described below, would probably be at least 20 cu. ft. per second. The sanitary sewage would therefore be only about 2 per cent of the storm sewage. The amount of the latter cannot be foretold nearly so close as 2 per cent. Thus the sanitary sewage would have no appreciable effect upon the size of the combined sewer, and can be neglected.

59. Minimum Sizes of Storm and Combined Sewers. In the case of sanitary sewers, 8 inches was stated to be the minimum allowable diameter (see Art. 47); but in the case of sewers carrying storm sewage, there is much greater danger of stoppages from dirt, sticks, and other debris washed in from the surface during storms. Hence *twelve inches should be the minimum allowable diameter for storm and combined sewers.*

60. Minimum Grades and Velocities for Storm and Combined Sewers. It was stated in connection with sanitary sewers (Art. 48), that the minimum allowable velocities to prevent deposits should be

TABLE VII

Minimum Grades for Storm and Combined Sewers

Shape	Material	Size	Minimum Grades to Give Velocities of 3 ft. per Sec.	Minimum Grades to Give Velocities of 4 ft. per Sec.
Circular	Pipe	12-in. Diam.	0.48	0.88
"	"	15 "	0.34	0.62
"	"	18 "	0.25	0.47
"	"	24 "	0.17	0.31
"	"	30 "	0.13	0.23
"	Brick or Concrete	3-ft. "	0.14	0.25
"	"	4 "	0.10	0.17
"	"	5 "	0.07	0.12
"	"	6 "	0.06	0.10
"	"	7 "	0.05	0.08
"	"	8 "	0.04	0.06
"	"	9 "	0.03	0.05
"	"	10 "	0.025	0.045
Egg-Shaped	"	2 ft × 3 ft	0.20	0.35
"	"	2½ " × 3 "	0.15	0.26
"	"	3 " × 4½ "	0.12	0.20
"	"	4 " × 6 "	0.08	0.14
"	"	5 " × 7½ "	0.06	0.10
"	"	6 " × 9 "	0.05	0.08
"	"	7 " × 10½ "	0.04	0.07

1¼ feet per second at the minimum depths of flow, which will require grades sufficient to give minimum velocities of 2 feet per second when the sewer flows full or half-full. For sewers carrying storm sewage, however, greater minimum velocities are necessary to prevent deposits, on account of the dirt, pebbles, and other heavy rubbish washed into them from the surface in times of storms. *For combined and storm sewers the minimum allowable grades should be steep enough to give a minimum velocity of 3 feet per second. If practicable without too great expense, 4 feet per second should be secured.*

61. General Explanation of the Calculation of Amount of Storm Sewage. When rain begins to fall upon the area drained by a storm sewer, the water falling in the immediate neighborhood of the outlet at once enters the sewer and begins to be discharged. As time passes and the rain continues, water arrives at the outlet from more and more remote portions of the drainage area, and the discharge at the outlet increases quite rapidly until water is being discharged from all portions of the drainage area at the same time. After that, any further increase is slow, being due only to a per cent of run-off slowly increasing as the saturation of the soil becomes more complete.

The *time of concentration* is the longest time required for water from the remotest points of the portion of the drainage area being considered, to reach the outlet of that portion.

The *general law of the heaviest rainfalls*, the ones which determine the sizes of sewers, is that the heaviest rates for short storms are much greater than the heaviest rates for long storms. *The longer the time, the less will be the average rate of the maximum storm lasting that time.*

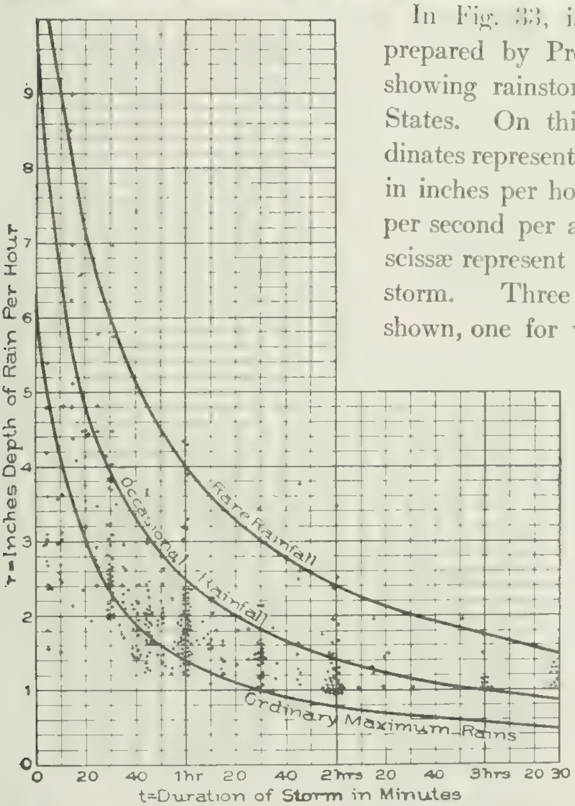


Fig. 33. Rates of Heavy Rainfall in the North Central States, Ohio, Indiana, Illinois, Missouri, Kansas, and Iowa.

In Fig. 33, is given a diagram prepared by Prof. A. N. Talbot, showing rainstorms in the Central States. On this diagram the ordinates represent the rate of rainfall in inches per hour (which = cu. ft. per second per acre), while the abscissæ represent the duration of the storm. Three curves are also shown, one for very rare rainfalls, one for ordinary heavy rains, and one intermediate. On the diagram each + represents one storm.

The storm causing the greatest rate of discharge in a storm sewer will usually be the maximum rain lasting a length of time equal to the time of concentration. If a time less than this be taken, water will not be discharged at the outlet from all parts of the drainage area at once, and that from near the outlet will have a chance to run away before that from the remotest points arrives. On the other hand, if a time be taken longer than the time of concentration, the *heaviest* rate of the maximum storm lasting this long will be less than the rate of the maximum storm lasting a length of time just equal to the time of concentration; and since the storm is lighter the flow will be lighter.

Not all of the water falling on a drainage area will be carried away in the sewer. During and after the storm, some of the water is evaporated into the air, and some is absorbed into the soil. Some also accumulates on the surface, to flow off into the sewer after the rain has ended. *The engineer determines the percentage of the rain flowing off in the sewer, by estimating the percentage of maximum run-off of the drainage area.*

The general method for calculating the amount of storm sewage for any particular drainage area, is therefore as follows:

(*a*) Calculate the *time of concentration,* or longest time of flow to the point for which the size of sewer is being determined.

(*b*) Calculate the *rate of maximum rainfall* corresponding to the time of concentration.

(*c*) Calculate the *percentages of impervious and pervious areas* on the watershed drained by the sewer.

(*d*) Using the percentages of impervious and pervious areas obtained in *c*, calculate the *maximum percentage of run-off,* or the percentage of the rate of the maximum rainfall which will be running off in the sewer under design at the end of the time of concentration.

(*e*) *Calculate the total maximum rate of flow of storm sewage,* by *multiplying together* the *drainage area,* the *maximum rate of rainfall* corresponding to the time of concentration, and the *maximum percentage of run-off.*

62. Calculation of the Time of Concentration. The time of concentration, which is the longest time required for water falling on the remote portions of the watershed to flow to the point for which the size of sewer is being determined, will be the sum of, (1), the time required for the water from roofs, yards, sidewalks, and pavements to reach the sewers by way of the gutter and street inlets, and, (2), the longest time required for the water to flow through a line of sewers to the point for which the size of sewer is being calculated.

(1) *Time Required for Water from Roofs, Gutters, etc., to Reach the Sewers.* This will usually be between the limits of 5 and 15 minutes, depending on the steepness of the slopes of the surface and of the gutters, on the distance the water must flow to reach the gutters and the distance it must flow in the gutters to reach the street inlets, on the character of the surface (whether it offers obstructions to flow or not), or whether the roofs are connected to the gutters or directly to

the sewers, etc. By looking over the ground carefully, and allowing for the above conditions in a general way, the time may be estimated as closely as the data will warrant, without special calculations. The upper limit of 15 minutes may be used when the gutters have a very light grade, and are two blocks long, and where the roofs discharge into the gutters instead of into the sewer direct.

(2) *Longest Time Required for the Water to Flow through the Sewers.* This is computed by taking the grades and sizes of the different parts of usually the longest line of sewers, and determining the corresponding velocities of flow by the use of the sewer diagrams, Figs. 27, 28, and 29, already given. From these velocities, and the lengths of the several portions of the sewer, the corresponding times required for the sewage to flow through each part can be readily computed, and their sum will be the time required. The designing must be begun at the upper ends of the sewers, so that we may know the sizes of sewer needed in computing the times of flow through each portion.

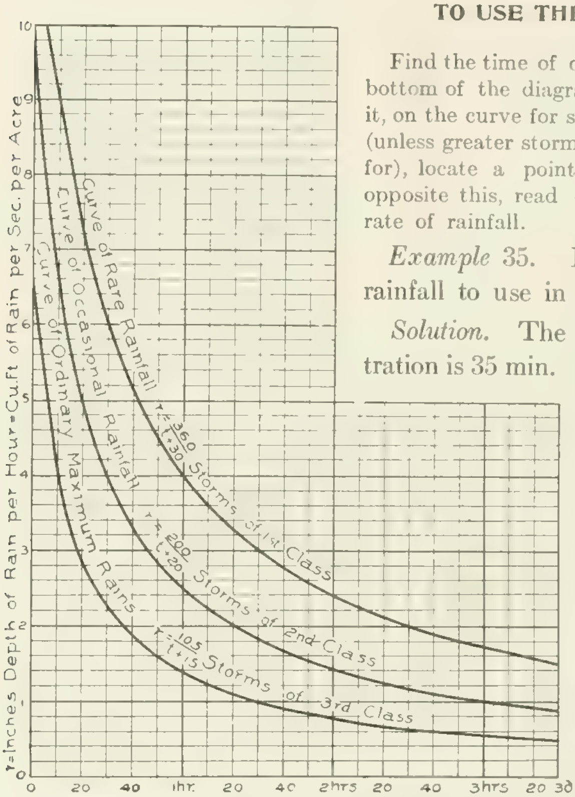
Example 34. Required the time of concentration in the following case: The longest sewer consists of 400 feet of 18-inch pipe sewer, grade 0.5 per cent; 800 ft. of 24-inch pipe, grade 0.3 per cent; 1,200 ft. of 36-inch brick sewer, grade 0.25 per cent; 2,400 ft. of 48-inch brick sewer, grade 0.17 per cent. The roofs discharge into the gutters, through which the sewage must flow 2 blocks at 0.5 per cent grade to reach a street inlet.

Solution:

Estimated for water from roofs and gutter to reach sewer	Velocity	Time
		15.0 min.
In 18-inch sewer, Fig. 27	4.2 ft. per sec.	1.6 "
" 24-inch " " 27	4.0 " " "	3.3 "
" 36-inch " " 28	4.0 " " "	5.0 "
" 48-inch " " 28	4.0 " " "	10.0 "
Answer. Total time of concentration =		35 "

63. Calculation of the Rate of Rainfall Corresponding to the Time of Concentration. In Fig. 34 are reproduced separately the three rainfall curves shown in Fig. 33. Storms of the 1st and 2d classes are rare, and are so very heavy that it would be excessively expensive to build sewers large enough for them. Hence sewers are usually built only large enough to provide for storms of the 3d class.

It is considered less expensive to suffer some damage from rare overcharging of the sewers than to build the greater sizes, though in case very valuable property would be damaged it may be wiser to provide for the heaviest storms.



t = Duration of storm in minutes = Time of concentration = Time required for water to flow from the remotest part of the area drained to the point under consideration on the sewer.

Fig. 34. Diagram Showing Rates of Maximum Rainfall to be Used in Calculating the Size of Storm Sewers.

TO USE THE DIAGRAM

Find the time of concentration at the bottom of the diagram. Vertically over it, on the curve for storms of the 3d class (unless greater storms are to be provided for), locate a point; and horizontally opposite this, read off on the left the rate of rainfall.

Example 35. Find the rate of rainfall to use in example 34.

Solution. The time of concentration is 35 min. Over this we read on the curve for 3d-class storms, 2.1 inches per hour.

Answer. 2.1 inches per hour.

64. Calculation of the Percentages of Impervious and Pervious Areas on the Sewer Watershed. The percentage of impervious area may be calculated in the following manner:

Take a typical unit of area, usually one average block, and divide it into different classes of surfaces, having different percentages of imperviousness, as follows:

(*a*) *Roof Area.* From the average size of buildings, and the average number of buildings per block which will be connected with the sewers or with the gutters, calculate the total roof area in the block. Take this at its full value if the roofs are connected directly with the sewers, but take only 90 per cent if the roofs are connected with the gutters.

(*b*) *First-Class Pavements.* Calculate the total area, per block, of brick, asphalt, stone block, and similar first-class pavements, with tight joints, and take 80 per cent of this area.

(*c*) *Second-Class Pavements.* Calculate the total average area per block, and take 60 per cent.

(*d*) *Third-Class Pavements.* Calculate the total average area per block of good macadam and similar pavements, and take 40 per cent.

(*e*) *Hard-Earth Roads.* Calculate the total average area per block of the traveled, hard-earth surfaces, and take 20 per cent.

(*f*) *Sidewalks.* Calculate the several total average areas per block of 1st, 2d, and 3d-class sidewalks, corresponding to the classes of pavements in *b*, *c*, and *d*, above. If these extend to the gutters, as in business districts, take the same percentages as for the corresponding classes of pavements—namely, 80, 60, and 40 per cent for 1st, 2d, and 3d-class sidewalks, respectively. But if the pavements are separated from the gutters by wide parking, as in the residence districts, take only one-half the above percentages namely, take 40, 30, and 20 per cent, for 1st, 2d, and 3d-class sidewalks, respectively.

Finally, add together all the reduced average areas per block (*a, b, c, d, e, and f*) *obtained as above explained, and divide the sum by the total area of the typical block. The quotient will give the percentage of impervious area.*

The percentage of pervious area is obtained by subtracting the percentage of impervious area from 100 per cent.

Example 36. In examples 34 and 35, assume the typical block to be 360 ft. square, center to center of streets, as follows:

Streets, 60 ft. wide; pavements, 30 ft. wide; asphalt on two streets; good macadam on the other two; cement sidewalks, 5 ft. wide, on all four streets.

One alley 20 ft. wide.

Lots, 12 in number, each 50 × 140 ft., each lot containing one house, the houses averaging 30 × 40 ft. the roofs connected with the gutter.

Calculate the percentage of impervious and pervious area.

Solution:

(*a*) Roofs, 30 × 40 × 12 × .90 = 12,960 sq. ft.
(*b*) 1st-Class Pavements, 2 × 15 × 360 × .80 = 8,640 "
(*d*) 3d-Class Pavements, 2 × 15 × 330 × .40 = 3,960 "
(*f*) 1st-Class Sidewalks, 5 × 1,210 × .40 = 2,420 "
Total impervious area per block = 27,980 sq. ft.
Total area of one block = 360 × 360 = 129,600 sq. ft.

Answer. *Percentage of pervious area* $= \dfrac{27{,}980}{129{,}600} = 21.58$ per ct.

Percentage of pervious area = 100 —21.58 = 78.42 per cent.

Mr. Emil Kuichling, M. Am. Soc. C. E., has calculated the percentages of impervious area in various cities of New York State, and his work has been repeated by Prof. H. N. Ogden,* who finds the percentage to vary with the intensity of population, as follows:

TABLE VIII
Approximate Percentages of Impervious Area in Cities

Population per Acre	Percentage of Impervious Area	Percentage of Pervious Area
5	4	96
10	9½	90½
15	15	85
20	20½	79½
25	26	74
30	31½	68½
35	37	63
40	42½	57½
45	47½	52½
50	52½	47½
55	58	42

Even very heavily populated sections in the largest cities will seldom have more than 80 to 85 per cent of impervious area.

Table VIII furnishes an easy method of making approximate estimates of the percentages of impervious area.

Example 37. In example 36, estimate the percentage of impervious area by Table VIII.

Solution. The typical block contains 129,600 sq. ft.; and $\dfrac{129{,}600\ (\text{sq. ft.})}{43{,}560\ (\text{sq. ft.})} = 3$ acres. The 12 houses at an average of 5½ persons per house, would give 66 persons per block = 22 per acre.

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* *Sewer Design*, p. 62.

Referring to Table VIII we find by interpolating, 22¼ per cent of impervious area, as compared with 21.6 per cent obtained above by the more exact method.

65. Calculation of the Maximum Percentage of Run-Off. Not all of the rain falling on the impervious area of a watershed will run off during the storm. Small amounts are evaporated or absorbed at once, for no city surfaces are absolutely impervious. A larger amount goes to fill up small depressions in the surfaces. A still larger amount accumulates on the surfaces of the watershed, making its way toward the sewer, the amount so accumulated and its rate of movement increasing as the storm continues at the same rate, until finally an equilibrium of flow is established, and the rate of the run-off from the impervious area becomes practically 100 per cent of the rainfall. Thus, the shorter the storm, the less the percentage of run-off from the impervious area; and hence sewer watersheds having the smallest times of concentration are likely to have the smallest percentages of maximum run-off from the impervious areas.

The maximum downpours which determine the size of the sewer, are often preceded by lighter downpours which saturate and partially flood the watershed. Hence *it will probably never be allowable to assume less than 75 per cent as the percentage of maximum run-off from the impervious areas of a sewer watershed, even with very short times of concentration, and comparatively little damage from overcharged sewers.*

With long times of concentration (say 45 minutes or more), and wherever great damage would be caused by overcharged sewers, 100 per cent of maximum run-off from the impervious areas should be assumed.

In the case of long-continued storms, the pervious area becomes gradually saturated, until some run-off occurs from it also. In the case of storms lasting several hours, such as cause the great floods in rivers, this percentage of maximum run-off may be quite high; but for sewers, the times of concentration, and hence the duration of the maximum downpour, are comparatively short—rarely as long as one hour.

For soils of average porosity and for moderate slopes, the percentage of maximum run-off from the pervious areas may be assumed to range from 0, for 15 minutes time of concentration, to, say, 20 for 1 *hour's time of concentration. For porous, sandy soils and flat slopes, assume 0 to 50 per cent, and for very impervious soils and very steep slopes, 125 to 150 per cent of the above percentages of maximum run-offs from pervious areas.*

Example 38. In examples 36 and 37, assume that the territory is a residence district, with moderate slopes and clay subsoil. Estimate the percentage of maximum run-off.

Solution. Since the time of concentration is only 35 minutes, while the damage from overcharged sewers would not be so great as in a business district, we shall assume 90 per cent maximum rate of run-off from the impervious area. For the pervious area, we interpolate roughly between 0 per cent for 15 minutes, and 17 per cent for 1 hour, and assume 8 per cent maximum rate of run-off.

.90 × 21.6 per cent = 19.4 per cent from impervious area.
.08 × 78.4 " " = 6.3 " " " pervious "

Answer. Total = 26 per cent maximum rate of run-off.

66. Summary of Methods of Computing Sizes of Storm Sewers. We may now summarize the methods of computing the sizes of storm sewers, described above in Articles 61 to 65, inclusive, as follows:

(*a*) Calculate the *time of concentration* (Art. 62), or longest time of flow from the remote portions of the sewer watershed to the point for which the size of sewer is being calculated.

(*b*) Calculate the *maximum rate of rainfall* (Art. 63) corresponding to the time of concentration.

(*c*) Calculate the *percentages of impervious and pervious areas* on the sewer watershed (Art. 64).

(*d*) From the percentages of impervious and pervious areas, and knowledge of the characteristics of the sewer watershed, calculate the *percentage of maximum run-off* (Art. 65).

(*e*) Calculate the *maximum rate of flow of storm sewage*, by *multiplying together* the *area of the sewer watershed in acres*, the *maximum rate of rainfall in inches per hour* (*b*), and the *percentage of maximum run-off* (*d*). The product will be the *cubic feet per second of maximum storm sewage flow.*

(*f*) Knowing the grade of the sewer, refer to Fig. 27, or Fig. 28, or Fig. 29, according to the shape and material of the sewer, and determine the size of sewer required to carry the maximum flow of storm sewage (*e*) when flowing full.

Example 39. In examples 34 to 38, assume that the sewer watershed is 5,280 feet long by 800 feet wide, and that the grade of the circular brick outlet sewer is to be 0.15 per cent. Calculate the required diameter.

(*a*) The time of concentration = 35 min. (see Ex. 34).

(*b*) The rate of maximum rainfall = 2.1 in. per hr. (see Ex. 35).

(*d*) The percentage of maximum run-off = 26 (see Ex. 38).

(*e*) The drainage area $= \dfrac{5{,}280 \times 800}{43{,}560} = 97$ acres.

$$97 \times 2.1 \times .26 = 53 \text{ cu. ft. per sec.}$$
$$= \text{maximum flow of storm sewage.}$$

(*f*) Referring to Fig. 28, we find, by interpolating between the 4-foot and 5-foot diameters, that for a grade of 0.15 per cent a diameter of 4 ft. 3 in. will be required for a circular brick sewer which can carry 53 cu. ft. per sec.

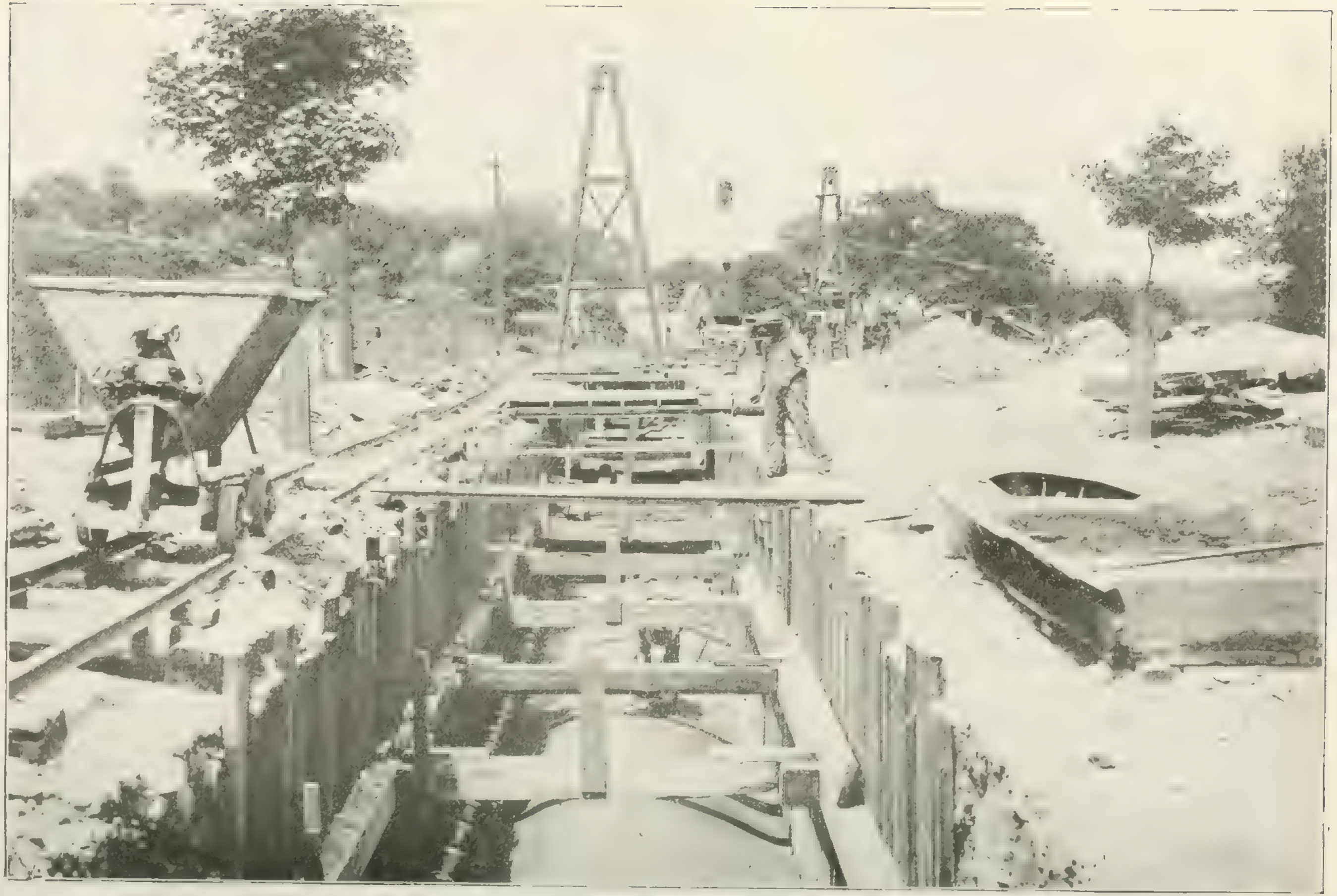
Answer. A 4 ft. 3 in. circular brick sewer.

GENERAL EXAMPLE FOR PRACTICE

67. Before proceeding further, the student should work out the following example in computation of the proper size of sewer:

Example 40. A thickly built-up sewer district, having a population of 35 persons per acre, ntains 160 acres. The slopes are very flat, and the soil is sandy and porous. The longest line of sewers is 6,000 feet; and the velocity of flow in the sewers averages four feet per second. The roofs are connected with the gutters, in which the longest flow is two blocks. Calculate the diameter of the circular, brick outlet sewer, laid to a 0.08 per cent grade (NOTE: Use Table VIII.)

Answer. A 6-foot circular brick sewer.



SEWER TRENCH IN BROOKLINE, MASSACHUSETTS

Metropolitan Sewerage System of Boston.

SEWERS AND DRAINS

PART II

LAND DRAINS AND SUBDRAINS

68. General Discussion of Land Drains. Definitions of sewers and drains were given in Art. 1. Land drains have for their object the reclaiming of wet lands, to render them suitable for cultivation. The reclamation of wet lands also greatly improves the sanitary condition of the vicinity.

There are two principal kinds of land drains—namely, *tile drains,* or lines of agricultural drain tiles laid a few feet beneath the surface of the ground, to remove ground water; and *drainage ditches,* or open channels, made to serve as outlets for the tile drains and to drain ponds and remove surface water.

69. Planning and Construction of Land-Drainage Systems. When a tile drainage system is projected, a competent drainage engineer should at once be engaged to do the necessary surveying, plan the system, and pass on the construction.

The surveying will include the obtaining of data for a complete map of the system; and each drain should be staked out, stakes being set 50 feet apart, and an elevation taken with a good level at each stake. All the work should be checked.

The engineer should then prepare for the landowner a complete map of the system, to a scale of 200 to 400 feet per inch; also a sheet of profiles, including a profile of each drain, showing the depth and grade at all points. Without such map and profiles, knowledge of the system may be lost, and, on some future occasion, when very badly needed, may be unavailable.

The engineer should plan as simple and regular a tile system as possible, adopting long, parallel, straight lines of tile when practicable, with as few junctions as possible.

The grades may be very light in case of necessity, and short tile drains have worked well even at level grades; but the lighter the grade, the greater should be the care used in construction.

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The minimum depths should usually be 3½ to 4 feet. Shallower depths do not drain out the soil so thoroughly; and tile, if laid 3½ to 4 feet deep, can be placed farther enough apart to more than make up for the cost of the greater depth.

The lines of tile should usually be placed from five to ten rods apart, depending on the soil—farthest apart in the most porous soil. The outlet should be built with special care; and a masonry wall should be constructed to hold the last length of tile.

For drainage ditches, careful surveys of the entire watershed must be made by a very competent engineer; and fully detailed plans and specifications must be prepared.

70. Contracts and Specifications for Tile Drains. The employer and the tile ditcher should sign a printed contract with detailed specifications, such as given herewith:

CONTRACT

It is hereby agreed between ...., employer, and ...., contractor, that the contractor shall, except for the furnishing of the tile along the ditch and the refilling of the ditch, entirely construct for the employer the following described drains:

....

....

....

....

....

....

It is further agreed that for the above work the employer shall pay the following prices:

....

....

....

It is further agreed that the employer.............................. ....furnish board free to the contractor and his helpers during active prosecution of the work.

It is further agreed that the contractor shall begin the work by........ ....and complete the same by..................

It is further agreed that all the above work and the payments therefor shall be in strict accordance with the specifications given below and with the engineer's maps, profiles, and plans, all of which are hereby made a part of this contract.

Witness the hands of the respective parties, this................day of ....A. D.....

........................Employer

......................Contractor

SPECIFICATIONS

1. *Staking Out the Work.* The work will be staked out by the engineer, and his stakes must be carefully preserved and followed.

2. *Digging the Ditches.* The digging of each ditch must begin at its outlet, or at its junction with another tile drain, and proceed toward its upper end. The ditch must be dug along one side of the line of survey stakes, and about ten inches distant from it, in a straight and neat manner, and the top soil thrown on one side of the ditch and the clay on the other. When a change in the direction of ditch is made, it must be kept near enough to the stakes so that they can be used in grading the bottom. In taking out the last draft, the blade of the spade must not go deeper than the proposed grade line or bed upon which the tiles rest.

3. *Grading the Bottom.* The ditch must be dug accurately and truly to grade at the depths indicated by the figures given by the engineer, measured from the grade stakes. At each grade stake, a firm support shall be erected; and on these supports a fine, stout cord shall be tightly stretched over the center line of the ditch and made parallel with the grade by careful measurements at each stake, using a carpenter's level. Supports shall be kept erected at at least three grade stakes, and the work checked each time by sighting over them. Intermediate supports shall be set and lined in by careful sighting wherever necessary, to support the cord every 50 feet. A suitable measuring stick shall be passed along the entire ditch, and the bottom in all parts made true to grade by measuring from the cord. The bottom must be dressed with the tile hoe, or, in the case of large tiles, with the shovel, so that a groove will be made to receive the tile, in which the tile will remain securely in place when laid.

4. *Laying the Tile.* The laying of the tile must begin at the lower end and proceed upstream. The tile must be laid as closely as practicable, and in lines free from irregular crooks, the pieces being turned about until the upper edge closes, unless there is sand or fine silt which is likely to run into the tile, in which case the lower edge must be laid close, and the upper side covered with clay or other suitable material. When in making turns, or by reason of irregular-shaped tile, a crack of one-fourth inch or more is necessarily left, it must be securely covered with broken pieces of tile. Junctions with branch lines must be carefully and securely made.

5. *Blinding the Tile.* After the tile have been laid and inspected by the employer or his representative, they must be covered with clay to a depth of six inches, unless, in the judgment of the employer or his representative, the tile are sufficiently firm so that complete filling of the ditch may be made directly upon the tile. In no case must the tile be covered with sand without other material being first used.

6. *Risk During Construction.* The ditch contractor must assume all risks from storms and caving-in of ditches; and when each drain is completed, it must be free from sand and mud before it will be received and paid for in full. In case it is found impracticable, by reason of bad weather or unlooked-for trouble in digging the ditch or properly laying the tile, to complete the work at the time specified in the contract, the time may be extended as may be mutually agreed upon by the employer and contractor. The contractor shall use all necessary precaution to secure his work from injury while he is constructing the drain.

7. *The Tile to be Used.* Tile will be delivered on the ground convenient for the use of the contractor. No tile shall be laid which are broken, or soft, or so badly out of shape that they cannot be well laid and make a good, satisfactory drain.

8. *Prosecution of the Work.* The work must be pushed as fast as will be consistent with economy and good workmanship, and must not be left by the contractor for the purpose of working upon other contracts, except by permission and consent of the employer. All survey stakes shall be preserved, and every means taken to do the work in a first-class manner.

9. *Subletting Work.* The contractor shall not sublet any part of the work in such a way that he will not remain personally responsible, nor shall any other party be recognized in the payment for work.

10. *Plant and Tools.* The contractor shall furnish all tools which are necessary to be used in digging the ditches, grading the bottom, and laying the tile. In case it is necessary to use curbing for the ditches, or outside material for covering the tile where sand or slush is encountered, the employer shall furnish the same upon the ground convenient for use.

11. *Payments for Work.* Every............weeks during the prosecution of the work, the contractor may claim and the employer shall pay 75% of the value of the work completed satisfactorily, the engineer being the arbiter in case of dispute as to the amount of work satisfactorily completed. The remaining 25% will be retained until the entire work is completed satisfactorily, as certified by the engineer after a final inspection, at which time the whole amount due shall be paid. Prior to any payment, the employer may require a correct statement of all claims incurred by the contractor for labor, materials, or damages on account of the work; and the employer may withhold payments until proof has been presented by the contractor of release of all liens against the employer on account of such claims.

12. *Duties of Engineer.* The engineer shall have authority to lay out and direct the work, and to inspect and supervise the same during construction and on completion, to see that it is properly done in accordance with the contract. His instructions should be fully carried out.

13. *Failure to Comply with Specifications.* In case the contractor shall fail to comply with the specifications, or refuse to correct faults in the work as soon as they are pointed out by the engineer or other person in charge, the employer may declare the contract void; and the contractor, upon receiving seventy-five per cent of the value of the completed drains at the price agreed upon, shall release the work and the employer may let it to other parties.

71. Benefits of Tile Drains. The advantages of tile drains may be enumerated as follows:

1. Tile drainage, by making the soil firm, enables earlier cultivation in the spring. Low ground drained can be cultivated earlier than high ground not drained.

2. Careful observations have shown that tile drainage makes the soil several degrees warmer in the spring. Scientific tests have

shown this increased warmth to be of the utmost importance in promoting the germination and growth of crops.

3. Tile drainage promotes pulverization of the soil, putting it in good condition to cultivate, and preventing baking and the formation of clods.

4. Tile drainage removes from the pores of the soil surplus and stagnant water, which would drown and destroy the roots of plants.

5. Tile drainage makes certain the proper "breathing" of the soil, or free circulation of air in its pores, which is essential to healthy plant growth.

6. Tile drainage establishes in the soil the proper conditions required for the satisfactory carrying on of the chemical processes necessary to prepare the plant food for its use by vegetation.

7. Tile drainage fits the soil for the vigorous life and action of the soil bacteria which are essential to preserve and increase its fertility and promote the growth of crops.

8. Tile drainage increases the depth of soil which can be reached by the roots of plants and drawn upon for plant food.

9. Because in them the roots of plants can penetrate deeper, where they are protected from heat and drouth and can reach the deep-seated moisture, tile-drained soils stand drouth better than undrained soils.

10. By putting the top 3-feet or 4-feet layer of soil into a porous condition, tile drainage enables soils to absorb rain water instead of discharging it over the surface, and so helps to prevent surface wash and consequent loss of fertility.

11. By causing this porous condition, tile drainage makes the upper 3 or 4 feet of soil into an enormous reservoir to catch the rain water and discharge it only slowly into the streams. Thus tile drainage prevents floods instead of causing them.

12. Tile drainage does away with irregular shaped fields, cut up by sloughs and ditches, and so cheapens cultivation.

Benefits of Large Ditches. Tile drainage is always preferred to open-ditch drainage if the drain is not too large. The advantages of large ditches may be enumerated as follows:

1. By furnishing channels to remove storm water, they prevent, if of ample size, the inundation of low-lying lands by floods and surface water.

2. They have a minor value for draining off the ground water from a narrow strip of land each side.

3. One of their main values is in furnishing outlets for tile drains, and in many places tile drainage is impracticable till outlet drainage ditches have been built.

72. Method of Computing Sizes of Tile Drains. The drained soil above the level of tile drains contains a large percentage of air-space in the pores between the soil particles; and this layer of porous soil acts like a great sponge several feet thick to absorb the rain as it falls. Hence the water reaches the tiles very slowly. It has been found that under average conditions tiles will not be called upon to carry more than ¼-inch depth of water in 24 hours. This equals 6,800 gallons per acre per day, or 4,352,000 gallons per square mile per day. The sizes of tile drains for average conditions may readily be taken from Table IX.

TABLE IX

Number of Acres Drained by Tiles Removing ¼-Inch Depth of Water in 24 Hours

GRADES		DIAMETERS OF TILE DRAINS										
Per cent	Inches per rod	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	15 in.	18 in.	20 in.	22 in.	24 in.
0.03	1/16					37	59	109	159	205	254	319
0.05	3/32		5	13	28	49	75	131	219	264	332	411
0.10	3/16	4	7	19	40	69	109	186	289	373	471	582
0.15	9/32	4	9	24	49	85	132	232	355	458	577	713
0.25	3/8	5	10	28	56	97	153	264	410	529	667	823
0.30	9/16	6	12	33	69	119	188	322	502	648	808	1,008
0.40	13/16	7	14	39	79	138	216	371	580	748	942	1,165
0.50	1	8	16	44	89	154	246	416	648	838	1,050	1,300
0.60	1 3/16	9	17	48	97	169	266	457	710	911	1,154	1,422
0.70	1 3/8	10	19	50	105	182	287	488	768	988	1,242	1,549
0.80	1 9/16	10	20	55	114	195	307	526	822	1,059	1,332	1,645
0.90	1 3/4	10	21	59	119	207	326	558	872	1,123	1,414	1,747
1.00	2	11	22	62	126	218	343	589	917	1,176	1,495	1,838
1.50	3	13	28	75	153	267	419	722	1,123	1,450	1,824	2,256
2.00	4	15	31	88	178	309	485	832	1,297	1,676	2,110	2,594
3.00	5 15/16	19	39	107	216	377	593	1,020	1,589	1,957	2,592	
4.00	7 15/16	22	45	123	253	437	683	1,176				
5.00	9 7/8	25	50	138	280	486	765					
7.50	14 7/8	30	61	169	344							
10.00	19 13/16	35	71	195								

Table IX is computed from the form of Poncelet's formula recommended for use with tile drains by C. G. Elliott, drainage expert to the U. S. Agricultural Department, Washington, D. C., who recommends the above sizes to drain ground water only. If surface water is also to be removed, as in the case of ponds without other outlets, the tiles will drain safely only one-half to one-third the number of acres given in the table.

When part of the land in the watershed is rolling, not requiring tiling, count only one-fifth to one-third of such rolling land, in addition to all of the low, flat land, in getting the size of tiles to remove ground water only.

Example 41. What size of tile laid to a 0.1 per cent grade will carry the under-drainage of 160 acres of flat land?

Answer. 15 inches.

Example 42. What size of tile to a 0.2 per cent grade will carry the under drainage of 240 acres, two-thirds rolling?

Answer. 80 acres flat land, *plus* one-third of 160 acres rolling, gives 133⅓ acres, requiring a 12-inch tile.

Example 43. What size of tile laid to 0.3 per cent grade will be required to remove both ground and surface water from a pond whose watershed includes 40 acres?

Answer. 10-inch. (NOTE.—Double or triple the area for both ground and surface water.)

73. Method of Computing Sizes of Drainage Ditches. Since drainage ditches must carry surface water as well as ground water, their capacities must be larger than those of tile drains for the same number of acres drained. It has been found by experience that they must carry from ¾-inch depth for small drainage areas, to ¼-inch depth for large drainage areas per day. Their size can be taken from Table X.

Example 44. What width of ditch, having a fall of 5 feet per mile, and a depth of water of 3 feet, will be required to drain an area of 5 square miles (3,200 acres)?

Answer. About 12 feet.

Example 45. What size ditch having a fall of 3 ft. per mile, and 9 ft. depth of water, will drain an area of three townships (69,120 acres)?

Answer. About 22 feet.

74. Method of Computing Sizes of Subdrains for Sewers. Sewer subdrains act like tile land drains to remove the ground water from the soil. Being deeper, they will drain wider strips of land—say averaging 16 rods wide, instead of 8 rods, for ordinary land drains in average soil; but also, owing to the greater depth, the water will reach the tiles more slowly, and this may offset the greater width drained. We may assume roughly that each subdrain may be called upon to remove ⅛-inch depth of water per day from a strip 16 rods wide, *which is the same thing as ¼-inch depth per day from a strip of land 8 rods wide.*

TABLE X

Number of Acres Drained by Open Ditches

		Depth of Water, 3 feet.				*Depth of Ditch, at least 4 feet.*				*Depth of Water, 5 feet.*				*Depth of Ditch, at least 6.5 feet*		
Grade		Average Width of Water								Average Width of Water						
Per cent	Feet per Mile	4 feet	6 feet	8 feet	10 feet	15 feet	20 feet	30 feet	50 feet	6 feet	8 feet	10 feet	15 feet	20 feet	30 feet	50 feet
0.02	1.0			725	970	1,570	2,240	5,300	18,400	980	1,470	1,900	5,000	7,150	23,800	43,800
0.04	2.1	400	690	1,000	1,360	2,250	4,700	7,470	26,100	1,390	2,090	2,800	7,200	20,100	33,500	62,500
0.06	3.2	492	850	1,260	1,690	2,770	5,770	18,400	31,900	1,710	2,560	5,100	17,600	24,700	40,800	75,500
0.08	4.2	572	980	1,460	1,950	4,820	6,670	21,400	37,400	1,980	2,980	6,100	20,400	30,000	48,800	88,000
0.10	5.3	636	1,100	1,630	2,180	5,360	7,440	23,700	41,400	2,220	5,010	7,600	23,400	33,400	51,500	98,000
0.15	7.8	791	1,330	2,010	2,670	6,600	19,000	30,200	52,100	2,720	6,300	17,100	28,700	40,500	66,700	120,000
0.20	10.6	905	1,560	2,310	4,720	7,870	21,800	35,000	60,300	4,820	7,300	19,500	33,000	47,000	77,000	139,000
0.25	13.2	1,020	1,740	2,660	5,300	17,500	24,600	39,000	67,700	5,370	16,300	21,900	37,500	53,000	86,000	155,000
0.30	15.8	1,100	1,970	2,900	5,850	19,400	26,800	42,700	74,000	5,900	17,900	23,900	40,700	57,000	94,000	170,000
0.40	21.1	1,300	2,290	5,050	6,740	22,200	30,800	49,400	85,700	6,830	20,600	27,700	47,000	67,000		
0.50	26.4	1,475	2,550	5,620	7,500	24,800	34,800	55,300	95,200	7,600	23,000	31,000				
0.60	31.7	1,600	2,790	6,230	16,500	27,200	37,700	60,400		16,700	25,200	33,900				
0.70	37.0	1,720	3,010	6,650	17,800	29,400	41,200			18,100	27,300					
0.80	42.2	1,850	4,850	7,170	19,100					19,000						
0.90	47.5	1,955	5,140	7,550	20,100					20,500						
1.00	52.8		5,400													

TABLE X—(Concluded)

Number of Acres Drained by Open Ditches

Depth of Water, 7 feet.							*Depth of Ditch, at least 9 feet.*	*Depth of Water, 9 feet.*				*Depth of Ditch, at least 11.5 feet*
GRADE		AVERAGE WIDTH OF WATER						AVERAGE WIDTH OF WATER				
Per cent	Feet per mile	8 feet	10 feet	15 feet	20 feet	30 feet	50 feet	10 feet	15 feet	20 feet	30 feet	50 feet
0.02	1.0	2,300	4,700	16,600	28,000	48,000	88,500	6,550	27,800	40,800	69,500	127,000
0.04	2.1	4,850	6,740	23,100	35,400	58,000	106,000	18,500	34,400	50,000	83,500	157,000
0.06	3.2	5,920	17,000	29,600	43,400	72,000	129,000	22,600	41,600	61,000	103,000	193,000
0.08	4.2	6,940	19,100	34,200	50,000	83,000	150,000	26,300	48,300	71,000	120,000	221,000
0.10	5.3	7,720	21,800	38,400	56,000	92,600	167,000	30,400	54,000	79,100	132,000	244,000
0.15	7.8	19,400	27,000	47,200	68,500	112,000	202,000	37,300	66,100	96,200	162,000	298,000
0.20	10.6	22,400	31,300	54,200	78,700	130,000	235,000	42,900	76,200	104,000		
0.25	13.2	25,000	34,800	60,500	88,000	146,000		48,000	85,300	125,000		
0.30	15.8	27,400	38,200	66,200	96,500			52,500	93,200			
0.40	21.1	31,700	44,100					60,800				
0.50	26.4	35,400										

Table X, for open ditches, is calculated by the well-known standard Kutter's formula, using a "coefficient of roughness" equal to 0.030. This coefficient of roughness is the value recommended by Kutter for channels in moderately good condition, having stones and weeds occasionally, and agrees with actual gaugings of drainage channels made at the Iowa State College. For ditches in first-class condition, the number of acres given may be increased about 25 per cent. The table has been calculated for ditches having sides with slopes of one foot horizontal to one foot vertical but is approximately correct for other slopes.

The capacity of the ditches has been made as recommended by C. G. Elliott, U. S. Agricultural Department drainage expert, as follows, the ditches to run not more than $\frac{8}{10}$ full for the capacities mentioned:

Above the upper heavy line, ¾-inch depth of water per 24 hours
Between the two heavy lines, ½-inch depth of water per 24 hours.
Below the lower heavy line, ¼-inch depth of water per 24 hours.

Local conditions may vary the size needed, and it is necessary to consult a drainage engineer in each case.

Hence the sizes required for sewer sub-drains may be taken from Table IX, calculating the number of acres drained by multiplying the total lengths of tributary drain tile, in feet, by 132 feet (= 8 rods), and dividing the product by 43,560 sq. ft.

The above method will give a capacity approximating 110,000 gallons per day per mile of tributary subdrains. As sewers are ordinarily distributed, it will give a capacity approximating 1,500,000 gallons per day per square mile of territory served by the sewers.

Example 46. Calculate the size of subdrains laid to a 0.25 per cent grade, required to serve as outlet for 30,000 linear feet of tributary subdrains.

Solution: $\frac{30{,}000 \times 132}{43{,}560} = 91$ acres = equivalent area drained for $\frac{1}{4}$-inch depth.

In Table IX, opposite the 0.25 per cent grade, we find that a 10-inch tile would be required.

Answer. 10-inch tile subdrain.

75. Cost of Tile Land Drains and Drainage Ditches. The cost of tile-drain construction in central Iowa in 1904, can be approximated from Table XI. Local prices should be determined before using the table for close estimates of work done elsewhere.

TABLE XI
Cost of Tile Drains

SIZE OF TILE	PRICE PER 1,000 FEET	WEIGHT PER FOOT	COST OF HAULING 1,000 FEET 5 MILES	COST OF DIGGING AND LAYING, PER ROD			REFILLING, PER ROD
				3 feet deep or less	Add per foot for additional depth over 3 feet		
					3–6 ft.	over 6 ft.	
3 in.	$ 16.00	5	$ 3.12	$ 0.35	$ 0.15	$ 0.30	2c.-5c.
4 in.	22.00	8	5.00	0.35	0.15	0.30	2c.-5c.
5 in.	30.00	10	6.25	0.35	0.15	0.30	2c.-5c.
6 in.	40.00	12	7.50	0.35	0.15	0.30	2c.-5c.
7 in.	50.00	15	9.37	0.35	0.20	0.35	2c.-5c.
8 in.	60.00	20	12.50	0.40	0.20	0.35	2c.-5c.
10 in.	95.00	30	18.75	0.45	0.20	0.35	2c.-5c.
12 in.	120.00	40	25.00	0.50	0.20	0.35	2c.-5c.
15 in.	250.00	50	31.25				
18 in.	400.00	80	50.00				
20 in.	600.00	100	62.50				
24 in.	800.00	125	78.12				

The cost of hauling given in Table XI is on the basis of $1.25 per ton, or $2.50 per day for a man and team, making two trips.

The prices for digging and laying given above include board furnished by the ditcher. If the farmer furnishes board, deduct about 20 per cent. The prices for digging and laying are for average ground, and should be increased for quicksand or very wet soils.

N. B. To all estimates it is wise to add 5 per cent to 10 per cent for contingencies and engineering.

Example 47. What will be the cost of 2,000 feet of 6-in. tile drain, 2½ miles from the tile yard, of which 1,000 feet is 4 feet deep, 500 feet 5 feet deep, and 500 feet 6 feet deep, in average soil?

Answer:

2,000 ft. of 6 in. tile @ $40.00	$80
Hauling 2,000 ft. 2½ miles, @ $3.75	7½
Digging and laying 60.6 rods 4 ft. deep, @ 50c	30½
" " " 30.3 rods 5 ft. deep, @ 65c	19½
" " " 30.3 rods 6 ft. deep, @ 80c	24
Refilling 121.2 rods (by team), @ 2c	2½
	$164
Add 10 per cent for engineering, etc.	16
Estimated cost	$180

Cost of Open Drainage Ditches. The cost of open drainage ditches is estimated by the cubic yard.

To calculate the number of cubic yards per foot of length of ditch, multiply the average width by the average depth, and divide by 27. Thus a 7-ft. by 12-ft. ditch contains $\frac{7 \times 12}{27} = 3\frac{1}{9}$ cubic yds. per foot length.

The cost per cubic yard in Iowa varies from 7c. to 18c., depending on the size of the job, the character of the soil, and other local conditions, including the certainty of the contractor getting his money promptly. The larger the work, the less is the cost per cubic yard.

HOUSE SEWERAGE

76. Definitions and General Description. A *house sewer* is a small branch sewer which connects the house with the street sewer. In Fig. 6 a general view of a house sewer is given.

A *soil pipe* is the main drainage pipe of the system of house plumbing, into which the different fixtures discharge. See Fig. 35.

A *trap* is a bend or depression in a pipe or drain, which remains constantly full of liquid, thus shutting off air-connection between the portions of the pipe or drain on opposite sides of the trap. See Fig. 35.

A general idea of an entire system of house sewerage can be obtained from Figs. 6 and 35, which see.

The house sewer and outlet for the cellar and foundation drains, extend from the street sewer to the house as shown in Fig. 6.

The iron soil pipe should begin a few feet outside the house, and extend full size through the roof, the separate fixtures discharging into the soil pipe, each protected by a trap, and all traps being vented, as shown in Fig. 35. The dotted lines in Fig. 35 show alternative plans sometimes adopted for house sewerage.

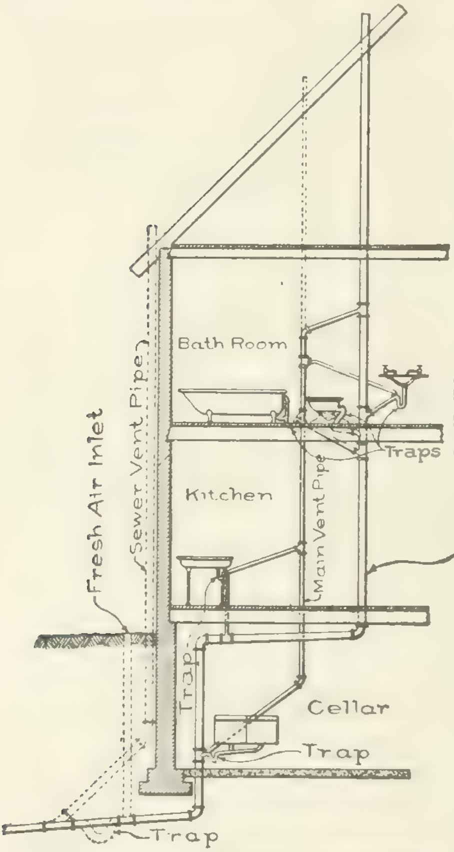


Fig. 35. Diagram of House Sewerage System.

77. House Sewers. House sewers (see Fig. 6) are usually made of vitrified sewer pipe the same as street sewers, and should be constructed with fully as much care. The joints should have gaskets of hemp or oakum, and be carefully cemented, the same as street sewers. (See Art. 33.)

Each piece of pipe should be laid to the exact grade by measuring from a grade string, the same as for street sewers (see Art. 98). The grade should usually be not less than 2 per cent. The house sewer should, if possible, be perfectly straight, both in alignment and in grade, from the house to the house connection at the sewer.

Inspection pipes should be placed just inside the lot line, as indicated in Fig. 6.

House sewers should usually be 4-inch circular pipe. If too large, they are more difficult to keep flushed clean, and they may carry to the street sewer things large enough to cause stoppages, improperly put into the house fixtures. Sometimes 5-inch or 6-inch house sewers are used.

78. General Principles of House Plumbing. The following general principles should be carefully observed in the installation of all house plumbing:

1. The iron pipe should begin a few feet outside the house, as vitrified pipe does not have tight joints and is liable to be broken, where it passes through the foundation wall, by uneven settlement.

2. No pipes carrying sewage should be allowed to be buried under the basement floor, unless placed in masonry-lined trenches with removable covers.

3. All pipes of the plumbing system should be iron or lead, with absolutely tight joints of lead, or screwed, or soldered.

4. In general, no pipes should be built into partitions or walls, where they cannot be gotten at, unless removable panels are placed over them.

5. All fixtures should be completely exposed to view, and should not be enclosed in woodwork. Sinks and washbowls, for example, should be supported on brackets or legs, with clear, open spaces under them.

6. All fixtures should be of durable, smooth, and non-absorbent material, such as porcelain or enameled iron. The least possible woodwork should be used.

7. All fixtures should be located in well-lighted and well-ventilated places.

8. Each fixture must be protected by a good trap. There must be no openings from the plumbing system into the interior of the house not thoroughly protected by traps sure to stay full of liquid.

9. Thorough ventilation of all pipes must be provided for.

10. All pipes must be laid to good grades, without sags, so as to drain completely and quickly.

11. The cellar and foundation drains should be connected with a sewer subdrain, if possible, and not with a sewer, owing to the danger of the water in the traps evaporating in dry weather when no water runs in the drains. If absolutely necessary to connect to the sewer, excessively deep traps should be used, to lessen the danger of evaporation.

79. Soil Pipes. The iron soil pipe begins, as already stated, a few feet outside the foundation wall. At this point a *disconnecting trap* is sometimes placed, as shown by the dotted lines in Fig. 35, in which case a *fresh-air inlet* must be placed on the house side of the trap, as also shown by dotted lines in Fig. 35, to permit complete ventilation of the soil pipe.

The soil pipe should extend full-sized and without any obstruction, a few feet above the roof. It should everywhere be readily accessible, and will naturally be placed in the location most convenient for attaching the fixtures.

The soil pipe is usually 4 inches in diameter, made of cast iron, with air-tight, leaded and calked joints.

80. Traps. The best traps are simply *smooth bends* in the plumbing pipes, giving depressions which stand full of liquid. If the curves are not smooth, or if there are sudden changes in size, the danger of stoppage is increased. The depth from the highest level of the water in the trap to the top of the liquid in the lowest portion, is called the *seal* of the trap. Traps are necessary evils in plumbing systems, as they tend to cause stoppages.

The seals of traps may be forced by any compression or rarefaction of air in the plumbing pipes, such as may be caused by *plugs* of sewage from other fixtures descending the pipes, unless a *vent pipe* is extended from the *crown* or highest point of each trap on the side next to the soil pipe, as shown in Fig. 35.

Traps should be located as closely as possible to the fixtures they are to protect.

81. Ventilation. The vent pipes from the traps mentioned in Art. 80, above, and shown in Fig. 35, serve also to secure ventilation of branch pipes. They should unite in a *main vent pipe*, 2 inches in diameter, as shown in Fig. 35, and this may turn into the soil pipe above the highest fixture, or may extend independently above the roof, as shown by the dotted lines in Fig. 35.

The extension of the main soil pipe unobstructed through the roof, with admission of air from the sewer (or through the fresh-air inlet if a disconnecting trap is used), together with the trap vent pipes and the main vent pipe, as shown in Fig. 35, insure ventilation of all parts of the plumbing system.

COST OF SEWERS, AND METHODS OF PAYING FOR THEM

82. Preliminary Estimates of Cost of Sewers. One of the first things which the sewerage engineer will be asked about sewers for which he has made plans, is what will be their cost. He must be able to answer this question readily, and with close approximation to the actual cost.

Many factors affect the cost of sewers, some of which cannot be exactly foretold. Among the things which can be closely ascertained in advance, are the sizes, lengths, and depths of the sewer, and the amounts of the various kinds of materials required. Among the things which cannot be exactly foretold, are the nature of the soil, the amount of ground water to be encountered, the weather conditions, and the labor conditions.

The competent engineer will thoroughly study all conditions which may affect the cost, before preparing his estimates, and even then will allow a liberal percentage for contingencies.

The engineer should have borings made to determine the character of the soil and the level of ground water, and should learn all he can of previous experience in the town with ditches and other excavations. Even then the actual soil often proves very different from what was anticipated.

After making the preliminary study and plans, the engineer tabulates the sewers by lengths, depths, sizes, and character, together with the manholes, lampholes, flush-tanks, and other items of the system. He then assigns a unit price to each item, after careful study of all conditions, and calculates the total cost.

The data of cost which follow are for average conditions only, and only for the localities named. They will need to be modified by the engineer to meet different conditions.

83. Cost of Pipe Sewers. In estimates of the cost of pipe sewers, the work is usually divided into the following items:

(1) *Trenching and Refilling.* This includes excavating the trench for the sewer, refilling it, and compacting the material after the sewer pipe is laid. Trenching and refilling are usually itemized according to depth, thus:

Trenching and Refilling under 6 feet depth
" " " " 6 to 8 feet depth
" " " " 8 to 10 feet depth
Etc., etc.

The cost of trenching and refilling will vary somewhat also with the diameter of the sewer; but this is often not separately itemized.

For estimates and bids, the lengths in linear feet of each depth of sewer are taken from the profiles, and listed in the tabulation.

(2) *Furnishing Sewer Pipe and Specials.* The pipe are usually specified to be delivered on board cars at the town where they are to be used. The amounts are usually itemized according to the diameters, thus:

Furnishing sewer pipe 8 inches diameter
" " " 10 " "
" " " 12 " "
etc., etc.

Specials are sometimes itemized separately, and sometimes included in the prices for furnishing pipe, the average distance apart being specified.

For estimates and bids, the total lengths of each size of pipe are ascertained and listed in the tabulation.

(3) *Hauling and Laying Sewer Pipe and Specials.* This includes taking the sewer pipe from the cars, hauling them to the sewer, furnishing cement, sand, and hemp or oakum, and laying the pipe according to the specifications. Some labor in excavating bell holes and a few inches at the bottom of the ditch shaped to fit closely the under side of the pipe, is also included. Hauling and laying are usually itemized according to the diameters of the pipe, thus:

Hauling and Laying sewer pipe and specials, 8 inches diameter
" " " " " " " 10 " "
" " " " " " " 12 " "
Etc., etc.

The lengths of each size are listed for estimates and bids, the same as sewer pipe.

In Fig. 36 is given a diagram for estimating the cost of pipe sewers and subdrains in the Middle West. It may be used elsewhere by noting local conditions and their variation from the conditions assumed, as follows:

(*a*) If the sewers are to be paid for promptly as the work progresses, in cash instead of in assessment certificates, deduct about 10 per cent.

(*b*) Get actual prices on sewer pipe delivered, and add about 8 per cent for additional cost of specials in the average residence district, and 16 per cent in the average business district.

(c) Ascertain the character of the soil, and the likelihood of encountering ground water. If the conditions are very favorable, the cost of trenching, refilling, and pipe laying may be materially decreased, even sometimes to 50 per cent of the figures shown in the diagram; while on the other hand, for very unfavorable conditions, the cost shown for these items will have to be increased, sometimes even to 150 per cent.

Example 48. Estimate the cost of a pipe sewer consisting of 1,200 ft. of 18-inch pipe averaging 16 feet deep, and 2,700 feet of 15-inch pipe averaging 12 ft. deep, under average conditions, together with a 6-inch subdrain.

Solution:

1,200 × 2.35 (from diagram) = $3,020 for 18-inch sewer
2,700 × 1.60 (" ") = 4,320 " 15 " "
3,900 × 0.15 (" ") = 585 " 6 ". subdrain
Answer. Total estimated cost = $7,925

84. Cost of Brick Sewers. The cost of a brick sewer may be estimated by determining separately the cost of the excavation and refilling and that of the brickwork. The number of cubic yards of each of these items is computed for 1 linear foot length of sewer; and the cost per linear foot is estimated by multiplying the results so obtained by estimated costs per cubic yard of excavation and brickwork respectively.

(1) *To calculate the number of cubic yards of excavation per linear foot length of sewer, multiply the average depth of sewer trench by the average width, and divide by 27.*

The *average depth* for a circular bottom will approximate the *average depth from the surface to the invert,* while the *average width* will be *at least as great as the internal diameter plus twice the thickness of the brickwork.*

Thus, for a 2-ring (9 inches of brickwork) circular sewer 6 feet in diameter, with grade line 12 ft. deep, the number of cubic yards excavation per linear foot of sewer is:

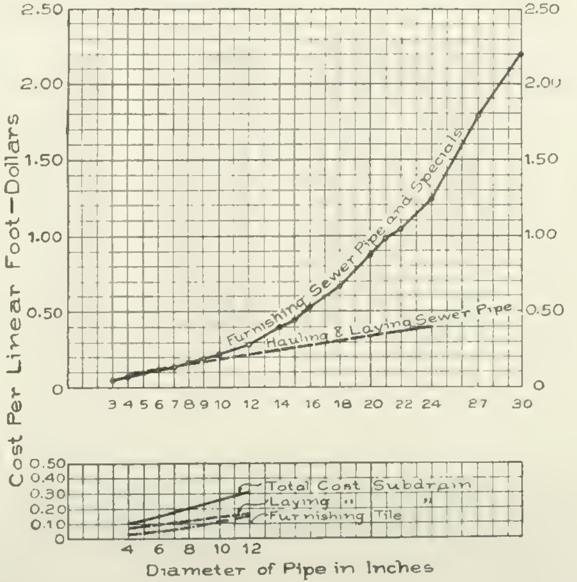
$$\frac{12 \times (6 + 1\frac{1}{2})}{27} = \frac{90}{27} = 3\tfrac{1}{3} \text{ cu. yds. per linear ft.}$$

The cost of sewer excavation and refilling varies usually from $0.20 per cu. yd. to $1.20 per cu. yd., averaging perhaps $0.50 to $0.75 per cu. yd.

DIAGRAMS FOR ESTIMATING COST OF PIPE SEWERS

Prepared from data collected for average conditions in the Middle West, 1906; ditches braced and partially sheathed, amount of water, moderate; common labor, $1.75 a day; payments to contractor, partly in assessment certificates.

For especially favorable or unfavorable conditions, the cost may vary 50 per cent either way, except for furnishing.



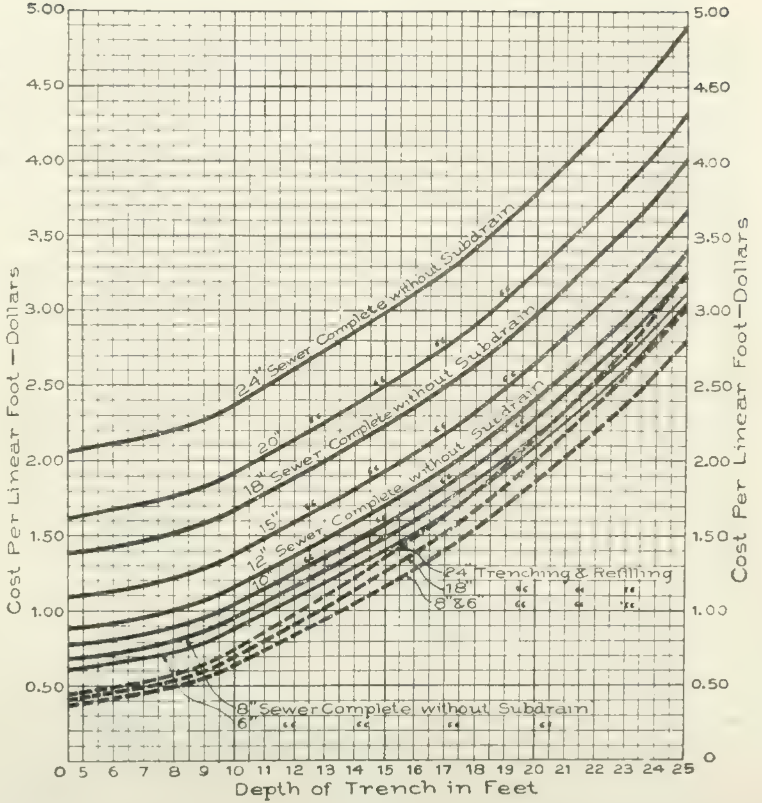


Fig. 36. Cost of Pipe Sewers.

Thus, for average conditions, fairly favorable, the cost of excavation for the 6-foot sewer, 12 feet deep, referred to above, would be 3⅓ × .60 = $2.00 per linear foot.

The favorable conditions for low cost per cubic yard, are, large sewers; neither great shallowness nor excessive depth; little water; soil firm enough not to require much bracing, yet not hard enough to require to be picked; and the use of excavating machinery. The opposites of these conditions give the unfavorable conditions.

(2) *The number of cubic yards of brickwork per linear foot* of brick sewers, may be taken from Tables XII and XIII, which are taken mainly from Gillette's *Handbook of Cost Data.*

TABLE XII

Cubic Yards per Linear Foot of Brick Masonry in Circular Sewers

Diameter	One Ring	Two Rings	Three Rings
2 ft. 6 in.	0.125	0.283	
3 " 0 "	0.147	0.327	
3 " 6 "	0.169	0.371	
4 " 0 "	0.191	0.415	
4 " 6 "	0.213	0.458	
5 " 0 "	0.234	0.502	0.802
5 " 6 "	0.256	0.544	0.867
6 " 0 "	0.278	0.589	0.933
6 " 6 "		0.633	0.998
7 " 0 "		0.677	0.063
7 " 6 "		0.720	0.128
8 " 0 "		0.764	1.191
8 " 6 "		0.807	1.260
9 " 0 "		0.851	1.325
9 " 6 "		0.895	1.390
10 " 0 "		0.938	1.456

TABLE XIII

Cubic Yards per Linear Foot of Brick Masonry in Egg-Shaped Sewers

Dimensions	One Ring	Two Rings	Three Rings
ft. in. ft. in.			
2 0 by 3 6	0.128	0.286	
2-6 " 3-9	0.154	0.341	
3-0 " 4-6	0.182	0.396	
3-6 " 5 3		0.451	0.725
4-0 " 6-0		0.506	0.808
4-6 " 6-9		0.561	0.891
5-0 " 7-6		0.617	0.974
5-6 " 8-3		0.673	1.056
6-0 " 9-0		0.729	1.140
6-6 " 9-9		0.785	1.223

The cost of brick masonry in sewers usually varies from $8.00 to $14.00 *per cubic yard, averaging perhaps* $9.50 *to* $12.00.

Thus, under average conditions, the cost, per linear foot, of the brick masonry of the two-ring, 6-foot circular brick sewer mentioned above, would be about 0.589 cu. yds. (from Table XII) × $10.50 per cu. yd. = $6.17 per foot. It will depend upon the grade of brick used, their cost per 1,000, the cost and proportions of cement and sand in the mortar, the wages of brick masons, the size and depth of the ditch, etc.

Example 49. Estimate the cost, under fairly favorable conditions, as to excavation and brickwork, of a 10-foot, 3-ring, circular brick sewer 1,875 ft. long, averaging 10 ft. deep.

Solution:

$$\text{Cu. yds. excavation per foot} = \text{about } \frac{10 \times 13}{27} = 5$$

(allowing 13 ft. width of trench, to provide a little extra room for bracing).

Since the conditions are fair, assume $0.60 per cu. yd. as cost of excavation and refilling.

The brickwork = 1.456 cu. yds. per linear foot (Table XII); and since the conditions are fair, we shall assume a cost of $9.50 per cu. yd.

Then the estimate will be as follows:

Excavation and Refilling,	5 × $0.60 =	$ 3.00 per lin. ft.
Brickwork	1.456 × 9.50	13.83 " " "
Total		$16.83 " " "

1,875 × 16.83 = $31,556 for total cost, to which, however, it may be wise to add, say, 5 to 10 per cent for contingencies unforeseen.

Answer. About $33,500.

85. Cost of Concrete Sewers. The cost of concrete sewers may be estimated by a method precisely similar to that described in Art. 84, above, for brick sewers—namely:

(1) *Compute the cubic yards of excavation per linear foot of sewer* $\left(= \frac{\textit{average depth} \times \textit{average width}}{27}\right)$, *and multiply by the estimated cost per cubic yard, which will be from* $0.20 *to* $1.20, *usually* $0.50 *to* $0.75.

(2) *Compute the number of cubic yards of concrete per linear foot of sewer*

$$\left(=\frac{\textit{total area of concrete in square feet in a cross-section of the sewer}}{27}\right)$$

and multiply by the estimated cost of the concrete per cubic yard, which will be from $6.50 to $12.00, usually from $7.50 to $9.50.

(3) *In the case of reinforced concrete sewers, compute the number of pounds of steel reinforcing per linear foot of sewer, and multiply by $0.04 to $0.05 per lb.*

The details of designs for concrete and reinforced concrete sewers vary so much that no tables can be given, as for brick sewers, showing the cubic yards of concrete per linear foot of sewer.

The cost of the concrete will depend upon the costs of cement, sand, and broken stone or gravel, and on their proportions; on the size and depth of the trench and its freedom from water; on the cost of labor, etc.

86. Cost of Manholes, Combined Manholes and Flush-Tanks, Flush-Tanks, Lampholes, and Deep-Cut House Connections. Under these headings the following data of cost will be found valuable:

Manholes. Under average conditions, the cost of brick manholes of the design shown in Fig. 9, will be *about $40 for 8 ft. depth of sewer.* For greater depths, *add about $3 per foot of additional depth.*

Combined Manholes and Flush-Tanks. Under average conditions, the cost of these may be estimated at $80, *plus $4 per foot of additional depth of sewer over 8 ft.* This is for about 500 gallons' capacity of the flush-tank part.

Flush-tanks of 500 gallons' capacity, under average conditions, may be estimated to cost *about $60 each.*

Lampholes, such as shown in Fig. 10, may be estimated at *about $10, plus $0.35 per foot of additional depth over 8 feet.*

Deep-cut house connections (see Fig. 8) may be estimated at $2.00 to $3.00 *each,* according to the depth of the sewer.

87. Engineering and Contingencies. In estimates of the cost of a sewer system, it is necessary to allow for unforeseen contingencies and for the cost of the engineering work. From 5 per cent to 20 per cent is usually added to the estimated cost on these accounts, depending upon the certainty or uncertainty of the knowledge of all the conditions.

EXAMPLE FOR PRACTICE

88. *Example* 50. Estimate the cost of the sewer system shown below, the conditions being assumed to be average. (NOTE: See Articles 84 to 87, inclusive.)

PRELIMINARY ESTIMATE OF COST OF SEWER SYSTEM FOR

ITEM	APPROX QUANTITY	COST	
		Unit	Total
4-ft. brick sewer, 2 rings 8 ft. average depth	850 ft.		
3-ft. " " 2 " 10 " " "	625 "		
24-in. pipe sewer, 9 ft. average depth	3,780 "		
18 " " " 11 " " "	1,740 "		
12 " " " 14 " " "	2,640 "		
8 " " " 10½ " " "	46,800 "		
Manholes 12 " " "	68		
Comb. M.H & F.T. 10 " " "	18		
Lampholes 11 " " "	38		
Total of above			
Engineering and Contingencies, 10 per cent of above.			
Total estimate of cost			*

* Answer. About $82,500.

89. **Methods of Paying for Sewers.** This is another question which comes up early in determining whether a city can or will build or extend a sewer system.

Three methods are in common use in paying for sewers, as follows:

(1) *The City as a whole may pay the entire cost.* When this plan is followed, all or part of the money may be raised by selling bonds, or all or any part may be raised at once by taxation.

In some States, cities are given a right to levy a *sewer tax* of a certain rate for a certain number of years in advance, and to anticipate the proceeds of this tax by issuing *sewer warrants.*

Often, when it comes to the construction of sewers, the City will be found to have already issued bonds to the highest legal amount, to build waterworks, an electric light plant, etc., so that no money for sewers can be raised from bonds.

(2) *The entire cost of the sewers may be assessed against the property abutting upon or adjacent to the sewer.* Here the legal principle is that the assessment must be in proportion to the benefit received. Property abutting directly upon the sewer receives the greatest benefit, and must be assessed for most of the cost. Sometimes the benefit will be in proportion to the number of feet frontage of the lots abutting on the sewer; and sometimes the benefit per unit lot is considered to be the same in all parts of the city, a large unit size of lot being adopted in the residence part of the city, and a much smaller size in the business section, with often an intermediate size between these two.

The "assessment" is levied upon the completion of the sewer, when the entire cost can be ascertained. Due notice to all property owners assessed must be given, so that they can present objections if they desire. Usually all property owners who desire are allowed to spread the payment of their assessments in equal installments over a considerable period of years, in which case *assessment certificates* are issued to cover the payments. The contractor is often required to take these certificates in payment for the sewer.

(3) *The cost of the sewers may be divided between the City and the property directly abutting upon or adjacent to the sewer.* This seems the fairest way; since, in the first place, the entire city receives benefit from improved sanitation, attractiveness to investors, etc., from a sewer constructed anywhere within its limits; and since, in the second place, any system of sewers for a city should be planned to give outlets of proper size to all parts of the district, which enlarges and deepens the sewers on many streets. On the other hand, the property along the sewer is benefited much more than the rest of the city, and should accordingly pay a much larger proportion of the cost.

The City Council usually has the right to decide what percentage of the cost is to be paid by the City and what by the property along the sewers.

PREPARATION OF PLANS AND SPECIFICATIONS FOR SEWERAGE SYSTEMS

90. Sewer Reconnaissance. When a sanitary engineer is called upon to prepare plans and specifications for a sewerage system, the first thing which he should do is to make a *reconnaissance* or general study of the entire city and its surroundings, with special reference to its sewerage conditions.

He visits the city and obtains copies of the best *maps* procurable. If these maps do not show the contours or elevations of the surface at different points, he obtains the best procurable information as to such elevations, and enters it upon the maps. Often the elevations of *street grades* will prove sufficient, if better and more detailed information is lacking. If *street profiles* are available, they will of course be of great value.

With maps thus prepared for the purpose, *he rides or walks over all parts of the city,* making himself thoroughly familiar with its *topography* and other features. Some of the information thus obtained may be entered upon the maps. He will note the *present density of population in different sections, and the prospects for future growth.* The presence or absence of *manufacturing industries,* and the future prospects in this line, are of importance. Statistics of the *past growth* of the city will be obtained. Full information regarding the character of the *water supply* and the amount and fluctuations of the *water consumption,* and the distribution of the *water mains* throughout the city, will be of great value. The local *labor conditions,* and the probable *local cost of cement, sand, brick, sewer pipe,* and other needed materials, must be ascertained. All possible information should be secured regarding the *ground water* and the *character of the soil* in different sections of the city. Information about old excavations and about wells can usually be secured, and will give much light on these points.

From his general study of the conditions, including especially the topography, the engineer must decide whether the system of sewerage shall be a *separate* system, or a *combined* system (see Articles 10 to 13, inclusive).

The question of the *outlet* will be one of the most important controlling points to be decided, and the engineer must carefully examine all possibilities in this line. The *number of outlets should be as small as feasible, one outlet being secured if possible.* The outlet must be low enough to drain thoroughly all portions of the district it serves, and should be chosen with a view to safe and satisfactory disposal of the sewage.

Sewage disposal is one of the very important points to be considered. In the past, most cities have simply discharged their sewage into the nearest available body or stream of water which it was considered could be used without causing damage or injunction suits on account of the pollution. At the present time, cities are being compelled more and more to provide means for purifying the sewage (see Articles 110 to 124); and the engineer, in choosing the outlet and planning the sewers, should always consider it probable that in the not distant future the city will be compelled to use some method of purification, and his plans should be so made as readily to permit this in the future, even if the city builds no sewage purification works at first.

During the reconnaissance, the engineer must constantly be recording the significant information he secures, in a neat and systematic manner in *a standard notebook*, which he keeps for the purpose. *Loose-leaf notebooks* of pocket size have many advantages for this purpose. In the same notebook, he should make all his preliminary computations.

On completing the reconnaissance, the engineer usually makes a *preliminary report* to the city officers, stating the conditions he has found, and his conclusions as to the general features of the system he has decided to recommend as best. He also usually presents at this time some rough estimates of cost.

The city then decides whether or not to adopt the general recommendations of the engineer, and whether to go on with the preparation of plans and specifications.

91. Surveys for Sewer Plans. After the reconnaissance, if it is decided to go ahead with the plans, the next step will be to make the necessary *surveys*. These may usually be divided into three principal parts as follows:

(1) *Surveys of Sewage Disposal Site.* In case a sewage disposal plant is to be built, a survey of the site must be made to secure the data needed for the design. Usually this will include data for a *contour map* of the entire tract, and borings or pits to determine the character of the soil.

(2) *Surveys for the Outlet Sewer.* Transit and level lines must be run, and profiles prepared, to determine the best route for the outlet sewer. Data must be secured for an accurate map and profile of the final location of this sewer.

(3) *Surveys for the Street Sewers.* Usually, existing plats can be found sufficiently accurate to give the dimensions necessary for constructing the *general sewerage map*, without special surveys. Small errors on these plats will not affect the general design, and will not be of much importance in view of the accurate surveys which must be made later during construction. Sometimes a few measurements with tape-line and transit must be taken in special localities. Usually the main part of the surveys for the street sewers consists in running *lines of levels* along all the streets on which there is possibility of planning sewers, in order to secure the data necessary to make the *sewer profiles* of all the sewers.

These levels should be referred to the *city datum*—that is, the reference level above which all city elevations are given. If such a datum has not already been adopted, one should be established, and marked by a *permanent bench-mark.* A six-inch iron pipe set six feet in the ground, filled and surrounded with concrete, makes a good, permanent bench-mark. The top, not quite filled with concrete, projects a little above the ground, and a copper bolt is set in the concrete at the top, the top of the bolt constituting the bench-mark. The pipe should have a hinged iron cap to protect the bolt.

In running the level, no effort should be made to trace out the main lines of sewers and their branches, but *each street should be surveyed by itself.* A zero point should be taken at some definite point (such as the center line, or one of the side lines, of a cross-street) at one end of the street, and *station points* 100 feet apart determined by continuous measurements with a steel tape. These stations should be numbered continuously from the zero point, intermediate points being located, in the usual way, by *plus* distances from the preceding station. Thus station 9 + 72 is 972 feet from the zero point.

The exact plus of each side line of each cross-street, and of points opposite other important things, should be determined and recorded in the notebook, to give measurements to be used in preparing the profiles, and in checking the map.

All lines of levels must be checked. At the end of each street, the leveling can be extended across to an adjacent street, and checked with the line of levels on that street.

Numerous bench-marks should be established around the city, located on permanent points, such as the tops of the foundation walls of buildings.

92. Sewerage Plans. From the data obtained by the surveys, the sewerage plans must be prepared. These will usually consist of a large number of separate sheets, the following being a list of the sheets of one particular set of plans, for a separate system of pipe sewers.

1. Index Sheet. (Giving the contents of all other sheets.)
2. General Sewerage Map.
3. General Map of Sewage-Disposal Plant.
4. Detailed Plans of Septic Tank. (For the Sewage-Disposal Plant.)
5. Detailed Plans of Filter Beds. (For the Sewage-Disposal Plant.)
6. Plans of Standard and Drop Manholes, and Lampholes.
7. Plans of Combined Manholes and Flush-Tanks.

8 to 33. Profile Sheets. (Showing profiles of all the sewers.)

In other cases, separate sheets may be needed for many other things, as, for example,

Details of Brick Sewers, of different sizes.
" " Concrete Sewers, " "
Plans of Flush-Tanks.
" " Catch-Basins.
" " Street Inlets.
" " Sewage Pumping Station.
Etc., etc.

For the sake of convenience and of neatness and system, *all the sheets of a set of sewerage plans should be made of a standard size* (*one or two can be made larger and folded to the standard size*), *and they should be bound together in regular book covers,* 18 inches by 24 inches being a convenient standard size of sheet for most cases.

Fig. 37 is a photographic view of such a cover containing a set of sewerage plans. The cover protects the sheets from injury, and is so arranged that any sheet can readily be removed and replaced A cover like that shown costs about $1.50.

The original drawings were all made on tracing cloth, except the profiles, which were made on transparent profile paper. Thus all the sheets can readily be reproduced by the process of blue-printing, and only the blue-print sheets are used on the work or by the City, the engineer retaining the original tracings in his office, where they can be kept safe.

In such a set of plans, the sheets should be numbered in order (see Figs. 38 and 39); and a *standard title* (see title of Fig. 38) should be adopted for all sheets which will require few changes of the different sheets.

Sewerage Map. In Fig. 38 is shown a reduced copy of an actual *sewerage map* of a separate system of sewers for a small town. The original size of the map shown was 36 inches by 24 inches, so that folding it once reduced it to the 18-inch by 24-inch size.

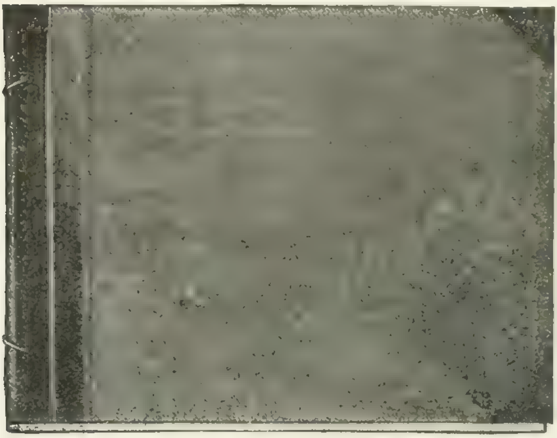


Fig. 37. Standard Cover for Sewerage Plans

The original scale of the map shown was 200 feet per inch; but for larger places, 300 feet or even 400 feet per inch may be sufficient, since large-scale maps of all the individual sewers appear on the profile sheets.

The lines of sewers in a system such as shown in Fig. 38, ought to be restricted as far as possible to the streets on which the lots front. Sewers on cross-streets add to the mileage of sewers without serving additional lots, and are useless except for connecting other sewers.

The manholes, lampholes, flush-tanks, etc., should be numbered systematically, something as shown in Fig. 38, no two structures of the same kind having the same number. This avoids danger of duplication where the same structure is shown on two or more sheets, as is often the case.

Sewer Profiles. In Fig. 39 is shown a sample profile sheet from an actual set of plans.

The original profile was made on "Plate B" transparent profile paper, so that the profiles can be reproduced easily by blue-printing, the same as the other drawings. The sheets were cut to the standard size, 18 inches by 24 inches, to bind with the other drawings.

The profiles should be made in systematic order of the streets, each *street completed before beginning the next,* instead of trying to follow up the main lines of the sewers and their branches.

The profile sheets show large-scale maps of the individual

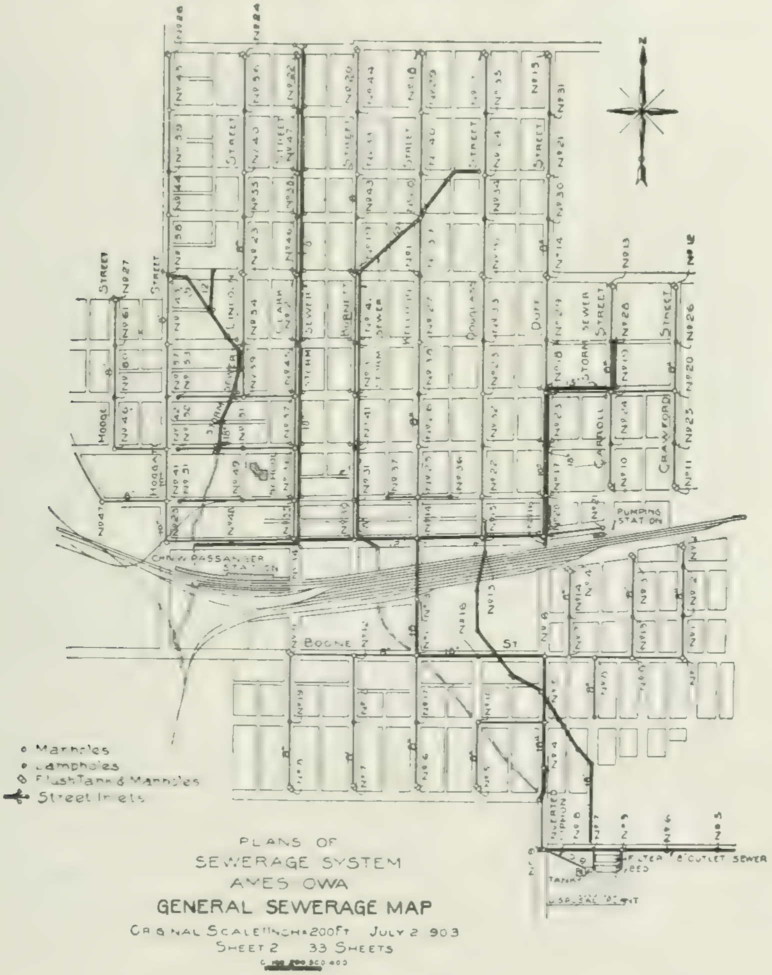


Fig. 38.

sewers immediately below their profiles, to permit the exact location of manholes, etc., and of the sewer itself in the street.

93. Specifications for Sewers. Besides the plans, it will be necessary for the sewerage engineer to prepare precise instructions regarding all matters of importance not fully shown by the plans, likely to come up during the construction of any part of the sewerage system. Such instructions are called *Specifications.*

An ordinary set of sewer specifications will consist of three parts:

(1) A *Notice to Contractors*, or form of advertisement for the city officers, to use in advertising for bids.

(2) A *Form for Proposal,* with suitable blanks, on copies of which, furnished by the city, all contractors are required to make their bids.

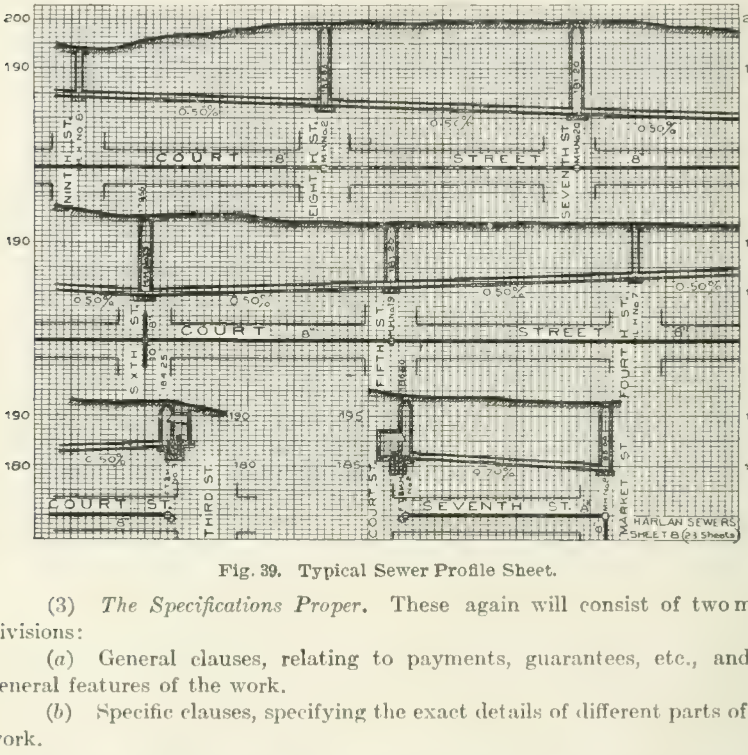


Fig. 39. Typical Sewer Profile Sheet.

(3) *The Specifications Proper.* These again will consist of two main divisions:

(*a*) General clauses, relating to payments, guarantees, etc., and to general features of the work.

(*b*) Specific clauses, specifying the exact details of different parts of the work.

A copy of an actual set of specifications for the construction of a separate system of pipe sewers, with a sewage-disposal plant, is given herewith:

CITY OF______________________, _________

SPECIFICATIONS

FOR

SEWERS AND SEWAGE-DISPOSAL PLANT

NOTICE TO CONTRACTORS

The Incorporated City of——————————,————., will receive sealed bids until————, ————, at ————————; (1) for the construction of a sewage-disposal plant, consisting of a sewage tank of about ————gals. capacity, and —— sand filter beds, each of about ——sq. ft. area; and (2) for the construction of sewers as follows: about —— ft. of 18-inch, —— ft. of 15-inch, —— ft. of 12-inch, —— ft. of 10-inch, and —— ft. of 8-inch, with suitable appurtenances, all in accordance with plans and specifications prepared by ————————, Engineer, ————————, and now on file in his office and with the City Clerk. All bids must be accompanied with certified checks, approximately in the amount of 5 per cent of the bid, made payable without recourse to the City of————————,————. The City reserves the right to reject any or all bids, to waive defects, and to accept any bid. All bids must be in sealed envelopes, marked on the outside "Sewerage Bids," and addressed to————————, City Clerk.

INSTRUCTIONS TO BIDDERS, AND GENERAL SPECIFICATIONS

(1) *Items.* The items of work intended to be covered by these specifications are those required for the entire completion of the System of Sanitary Sewers for the City of————————————, ————————, according to the plans prepared by————————, Engineer, and include the following:

(*a*) The construction of a Sewage-Disposal Plant, including a sewage tank of about ——— gallons capacity, and —— sand filter beds, each of about —— sq. ft. area, and including all valves, sewer pipes, outlets, etc.

(*b*) The construction of Sewers as follows:

18-inch.	Ft.
15-inch.	"
12-inch.	"
10-inch.	"
8-inch.	"
Manholes	"
Lampholes.	"
Combined Manholes and Flush-Tanks,	"

together with subdrains as directed by the City.

(2) *Application.* These general specifications and instructions to bidders shall apply to all items of workmanship or materials enumerated above or hereinafter mentioned.

(3) *Definitions of Terms.* Wherever the word "City" is used in these specifications, it shall be understood to mean the Incorporated City of————, ————., acting through the Mayor and Council, or their duly authorized representatives. Wherever the word "Contractor" is used in these specifications, it shall be understood to mean the person or firm employed to do all or any part of the work or furnish all or any part of the material for the Sanitary Sewerage System. Wherever the word "Engineer" is used in these specifications, it shall be understood to mean the Engineer employed by the City to design or supervise the construction of all or any part of the Sanitary Sewerage System.

(4) *Bids.* All bids must be on blanks furnished by the City for the purpose. The blanks can be obtained from ————————, City Clerk ————————, ————., or from ————————, Engineer, ————————, ————

All bids must be enclosed in sealed envelopes addressed to————, City Clerk,————, ———., and plainly marked on the outside with the words "Sewerage Bids."

Each bid must be accompanied with a certified check approximately in the sum of 5 per cent of the bid, and made payable without recourse to the City Treasurer, ————————,—————.

The City reserves the right to reject any or all bids, to waive defects, and to accept any bid.

(5) *Certified Checks.* The certified check mentioned above will be forfeited as damages to the Incorporated City of ——————, ————., unless the Contractor enters into contract and furnishes bonds satisfactory to the Mayor and Council within 12 days after the contract has been awarded to him. Certified checks not so forfeited shall be returned to the bidders as soon as the contract is signed and satisfactory bonds are furnished.

(6) *Bond.* A bond satisfactory to the Mayor and Council shall be furnished by the Contractor, approximately in the amount of 50 per cent of the contract price.

(7) *Time.* The Contractor shall begin work within 3 weeks after the contract is awarded to him, and shall entirely complete the work on or before ——————————, —————.

(8) *Sub-contracts.* No sub-contracts shall be awarded to parties unacceptable to the City.

(9) *Progress of the Work.* The work shall be prosecuted at a rate to enable its completion within the time specified; and should the Contractor fail to do this, the City may, after giving ten days' written notice, take over the work and complete it at the Contractor's expense.

(10) *Penalties.* Should the Contractor fail to complete the work at the time specified, he shall forfeit to the City a sum equal to all damages to it resulting from the failure to complete the work at the time specified.

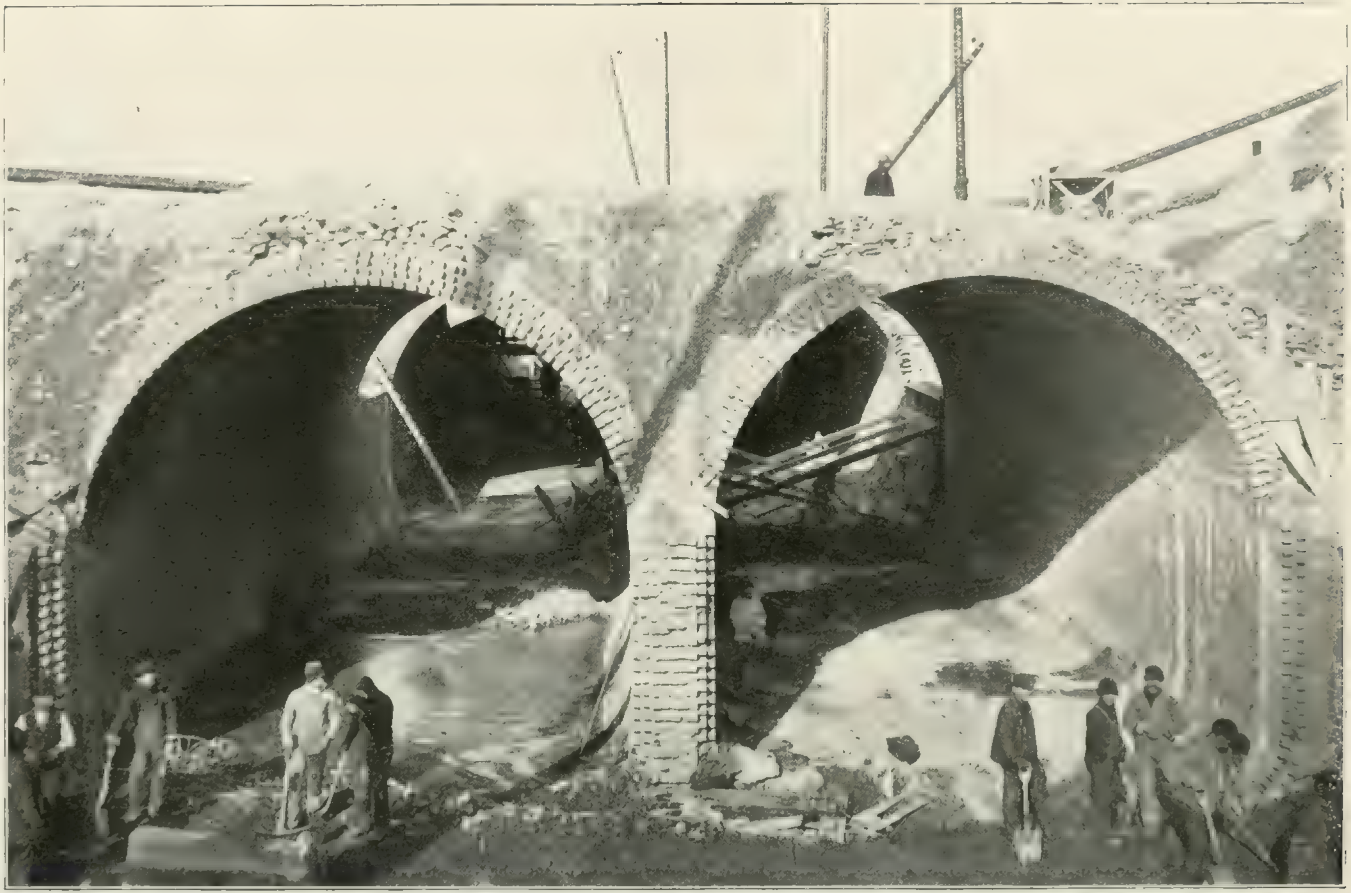
(11) *Delays.* No claims for damages shall be made against the City on account of delays in delivery of materials or performance of work; but should there be unduly prolonged delays in the delivery of any materials or the performance of work on the part of the City, the Contractor shall be entitled to corresponding extension of time.

(12) *Obstructions.* The Contractor shall carry on the work in such a way as to obstruct the city streets as little as possible, and so as not at any time entirely to shut off passage of teams and pedestrians at any place. He shall provide temporary crossings satisfactory to the City for this purpose wherever necessary.

(13) *Precautions.* The Contractor shall take all necessary precautions to prevent injury to the public or to his workmen or to stock, such as providing crossing plank, fencing off his work, keeping lanterns burning at night, etc. He shall hold the City harmless against all claims for damages.

(14) *Plans and Specifications.* The City's plans and these specifications shall be a part of the contract, and all materials and workmanship shall be in accordance with them.

(15) *Supervision.* All materials and workmanship shall be subject to the supervision and inspection of the City and of its Engineer or other authorized representative. Instructions as to the details of the work shall be carried



SECTION OF A SAND-CATCHER

Metropolitan Sewerage System, Boston, Mass.

out, and rejected materials and work shall be promptly removed at any time discovered.

(16) *Quality of Materials and Workmanship.* All workmanship and materials shall be of the best quality.

(17) *Quantities.* The quantities named in the notice to contractors, the form of proposal, or in these specifications, are approximate only. The City shall have the right to vary them; and, if so varied, the total contract price shall be increased or diminished at the rates named per unit in the contract.

(18) *Extra Work.* No extra work shall be done without written orders from the City or its specially authorized representatives placed in charge of the work. In case extra work becomes necessary, it shall be done by the Contractor if so ordered, and shall be paid for by the City on the basis of actual cost, *plus* 10 per cent; but no extra work will be paid for unless ordered in writing by the proper authority at the time undertaken.

(19) *Changes in Plans.* The City shall have the right to make changes in plans. In making such changes, the unit prices named in the contract shall be used, as far as possible, in calculating the changes in price on account of changes in the plans, and where these do not apply, the changes in price, unless a special agreement between the City and the Contractor as to prices is made at the time the changes are ordered, shall be calculated on the same basis as extra work.

(20) *Claims.* The Contractor shall guarantee the payment of all just claims for materials or labor in connection with his contract. Preliminary to the payment for any work, he shall, if required by the City, present evidence satisfactory to the Mayor and Council that all bills for materials and labor have been paid, and any or all payments may be reserved until such evidence has been presented. If the payment of any just claim shall be deferred more than four weeks after written notice has been given concerning it to the Contractor, the City may proceed to pay such claim out of any money due the Contractor.

(21) *Payments.* Payments shall be made as follows:

(NOTE: Fill in, in this blank, whether the payment is to be made in cash, in sewer warrants, sewer certificates, or otherwise. Also whether payments are to be made monthly as the work progresses, or reserved until completion, the former plan being usual for cash payments, and the latter for payments in certificates.)

All payments shall be on estimates prepared by the Engineer and approved by the Council, of materials delivered and work performed; and in case of all payments made prior to the completion of the contract, 15 per cent of the estimate shall be reserved until the final payment on completion of the work.

No payment shall be considered as releasing the Contractor from obligation to remove and make good defective work and materials when discovered at any time.

Two per cent of the total cost may be reserved by the City for one year after the completion of the work, and any part of this reserve may be used to make good defects developed within that time from faulty workmanship and materials, provided that notice shall first be given the Contractor, and that he may promptly make good such defects himself if he desires.

(22) *Guarantee.* The Contractor shall guarantee the workmanship and materials for one year, and keep the system in repair after completion, as provided in clause 21 above.

(23) *Risks.* All materials and work will be at the risk of the Contractor until the final acceptance of the same.

(24) *Cleaning Up.* On completion of each part of the work, all rubbish and unsightly materials must be removed and disposed of as directed by the City, and the streets and grounds left in neat condition. For the sewers, each two blocks must be cleaned up immediately on completion, and on the completion of the entire contract shall be further put in good shape if needed.

MATERIALS

(25) *Vitrified Sewer Pipe.* All sewers shall, unless special permission be given to use cement sewer pipe, be constructed of first-quality salt-glazed, vitrified clay sewer pipe, of the hub-and-spigot pattern, of standard thicknesses and dimensions of hubs. The dimensions of hubs shall be sufficient to leave an annular space for cement of at least ⅜-inch thickness for 8-inch and 10-inch pipe, and ½-inch thickness for larger diameters.

Pipe may be furnished in lengths of 2, 2½, or 3 feet. All pipe and specials shall be sound and well burned, with a clear ring, well glazed and smooth on the inside, and free from broken blisters, lumps, or flakes which are thicker than ⅙ the nominal thickness of the pipe and whose largest diameters are greater than ⅛ the inner diameter of said pipe; and the pipe and specials having broken blisters, lumps, and flakes of any size shall be rejected unless the pipe can be so laid as to bring all of these defects in the top half of the sewer. No pipe having unbroken blisters more than ¼ inch high shall be used, unless these blisters can be placed in the top half of the sewer. Pipes or specials having fire-checks or cracks of any kind extending through the thickness shall be rejected.

No pipe shall be used which, designed to be straight, varies from a straight line more than ⅛ inch per foot of length; nor shall there be any variation between any two diameters of a pipe greater than $\frac{1}{24}$ the nominal diameter.

No pipe shall be used which has a piece broken from the spigot end deeper than 1½ inches or longer at any point than ¼ the diameter of the pipe; nor which has a piece broken from the bell end if the fracture extends into the body of the pipe, or if such fracture cannot be placed at the top of the sewer. Any pipe or special which betrays in any manner a want of thorough vitrification or fusion, or the use of improper or insufficient materials or methods in its manufacture, shall be rejected.

(26) *Sewer-Pipe Specials.* All T- and Y- junction curves, etc., required shall be furnished and set without extra charge, and shall conform to the pipe specifications as to quality. Y's for house connections may be required every 25 feet on the average, and shall be closed by vitrified stoppers cemented over sand.

(27) *Drain-Tile.* All drain-tile shall be best-quality vitrified agricultural drain-tile in one-foot lengths. All junctions and inspection openings shall be made with suitable T- and Y- junctions and curves, furnished and set without extra charge.

(28) *Brick.* All brick used on the work shall be sound, partially vitrified, well-shaped brick, equal to No. 2 paving brick.

(29) *Cement.* All cement used shall be ——, ——, ——, ——, ——, ——, or —— Portland Cement, perfectly fresh, and not damaged in any particular. It shall be subject to the Standard specifications of the American Society for Testing Materials, and will be rejected if it does not meet these requirements. All cement shall also be subject to close inspection as it is used on the work, and damaged cement will be rejected and must be promptly removed.

(30) *Sand.* All sand shall be clean, sharp, and coarse. All sand for mortar for sewer joints or brick masonry must have all pebbles screened out.

(31) *Broken Stone and Pebbles.* The aggregate for concrete shall consist of either broken stone or screened pebbles passing a 2½-inch ring for ordinary concrete, and a 1½-inch ring for the septic tank. The materials must be sound and hard and durable. The sand must be screened out of pebbles used; but the fine materials need not be screened out from broken stone, a reduction being made in the amount of sand used, approximately equal to the amount of stone dust.

(32) *Cast Iron.* All cast iron shall be good, tough, gray iron, free from defects. Castings shall be smooth and free from blowholes or other flaws.

(33) *Cast-Iron Water-Pipe.* All cast-iron pipe shall be cast of the hub-and-spigot pattern, of standard weights for water-pipe for light pressures. The pipe shall be well coated.

(34) *Valves.* All valves shall be iron body, brass-mounted, hub-end, double-gate, water valves, well coated, of the ———— or of equal make acceptable to the Engineer.

(35) *Valve Boxes.* All valve boxes shall be ———— extension boxes with 5¼-inch shafts, or some equal make acceptable to the Engineer.

MORTAR AND CONCRETE

(36) *Mortar.* All mortar for brickwork or other masonry shall be made of one part of Portland cement to three parts of sand; and all mortar for sewer joints, of one part of cement to one of sand, both ingredients being measured loose and thoroughly mixed. All mortar shall be mixed fresh as used, and any mortar which has begun to set shall be thrown away and not used at all on the work.

(37) *Concrete.* All masonry shown on the plans to be made of concrete shall be constructed with Portland cement, sand, and either broken stone or screened pebbles passing a 2½-inch ring, in the proportions 1-3-5 for ordinary work, and 1-2-3½ for the septic tank, the cement being measured packed as it comes in sacks or barrels, and the sand being measured loose as thrown into the measuring box with shovels. The proportions shall be determined by suitable measuring boxes, or by the use of wheelbarrows. In case of hand-mixing, the sand and cement shall first be thoroughly mixed dry until the color of the mixture is uniform. They shall then again be mixed with water, and then again with the freshly wet aggregate, each mixing being very thorough, and sufficient to secure perfect mixture of the materials. If a machine mixer is used, it shall be of a make acceptable to the Engineer, and shall be so used as to give very thorough mixing. Just enough water shall be

used to make the concrete slightly quake when thoroughly rammed, the water freely flushing to the surface under the ramming.

In depositing, the material shall be deposited in layers not exceeding 6 inches in height, and thoroughly rammed. Where work is left for the night, the layers shall be racked back. Where fresh concrete is deposited on work which is already set or begun to set, the surface shall first be thoroughly cleaned and wet, and washed with a coat of liquid neat cement. After the concrete is deposited, great care shall be taken not to disturb it until the work is thoroughly set. The work shall be protected from the sun, and shall be wet from time to time, until it is thoroughly set.

TRENCHING, PIPE-LAYING, REFILLING, ETC.

(38) *Excavation.* The excavation shall be made exactly to line and grade as indicated by stakes set by the Engineer. At the bottom, the trench shall have a clear width at least one foot greater than the external diameter of the body of the pipe. The last four inches shall be excavated only a few feet in advance of the pipe-laying, by men especially skilled, measuring from an overhead line set parallel to the grade line of the sewer. The bottom of the trench shall be rounded to fit the pipe; and holes shall be dug for the bells so as to give a uniform bearing, and permit the proper construction of the sewer joints on the under side of the pipe. The earth taken from the trench shall be deposited neatly at the sides, in such manner as to obstruct the streets as little as possible; and a clear space of two feet next the trench shall be left on the side on which the Engineer places his stakes. Great care shall be taken to preserve and not to cover up the Engineer's stakes.

(39) *Sheathing.* Wherever necessary to prevent caving of the banks or injury to adjacent pipes or buildings, the Contractor shall, at his own expense, brace and sheath the trenches sufficiently to overcome the difficulty to the satisfaction of the Engineer. If such bracing and sheathing is left permanently in the trench by order of the Engineer, it shall, on refilling, be cut off one foot below the surface and shall be paid for by the City at the price named in the contract; but otherwise the Contractor will receive no extra compensation for it.

(40) *Water in Trenches.* In general, all water encountered in trenches must be drained away through the sub-drains or pumped or bailed out, and the trench must be kept dry for the pipe-laying. In no case shall the sewers be used as drains for such water, and the ends of the sewer shall be kept properly blocked during construction. All necessary precautions shall be taken by the Contractor to prevent the entrance of mud, sand, or other obstructing material into the sewers or subdrains; and on completion of the work, any such materials which may have entered must be cleaned out and the sewers and subdrains left clean and unobstructed.

(41) *Refilling.* In refilling, earth free from stones shall be carefully placed by hand under and around the pipe and to the height of two feet above the top of the sewer, and thoroughly and carefully rammed in layers of not more than six inches' depth.

The remainder of the refilling shall be carefully done. Scrapers may be used if desired. The refilling shall be thoroughly flooded by the Contractor according to the direction of the Engineer, the City furnishing the water free at the hydrant; but the refilling shall be carried on in such a way that water is taken only as directed by the Waterworks Superintendent, and so that not more than —— gallons of water shall be required in any one day.

Where the trench is not flooded, it shall be left neatly rounded off on top to a height of twice as many inches as the top width of the trench in feet; and the City may from the 2 per cent reserve make good any settlement below the street surface within one year from the date of completion, notice being first given the Contractor, who may promptly do the work himself if he desires.

All surplus material shall be removed to such point within the limits of the sewer district as may be designated by the City; and in case of deficiency of material, it shall be supplied by the Contractor. The street surface shall be left in neat, sightly condition.

(42) *Foundations.* In case the material encountered should be such as not to be suitable for foundations for the sewer, the Engineer shall direct the character of foundations to be constructed, and this shall be paid for by the City as extra work.

(43) *Protection to Buildings.* The Contractor shall take all necessary precautions to protect building and other structures adjacent to the sewer trenches from injury on account of his work, and shall be responsible for all damages to such structures.

(44) *Existing Sewer and Water Mains.* Wherever existing sewers or water mains are encountered in the work, all necessary precautions shall be taken to prevent injury to them; and in case of an injury, it shall be made good by the Contractor without additional compensation. In case any sewer, drain, or water main should be encountered whose present grade should require changing on account of the new sewers, the work necessary for this shall be performed by the Contractor according to the directions of the Engineer, and shall be paid for as extra work.

(45) *Pipe-Laying.* In pipe-laying, each piece must be set exactly to grade by measuring from the invert to a tightly stretched cord set parallel to the grade line, according to stakes or marks given by the Engineer, and supported at least every 25 feet. In making each joint, a gasket of oakum or hemp freshly dipped in cement grout must first be used and packed into place, so as to make the inverts match exactly, giving a smooth, true flow-line. The joints shall afterwards be tightly packed full and beveled off with 1 to 1 Portland cement mortar; but the cementing must be done at least two pipe lengths behind the pipe-laying. The bell-holes must then be immediately packed with sand to hold the cement in place. Great care must be taken to leave no projecting cement or strings of gaskets on the inside of the sewer, and to make all joints as nearly water-tight as possible. Especial care must be taken in forming the joint on the under side of the pipe.

(46) *House Connections.* At points indicated by the Engineer opposite each lot, and at such other points as may be indicated by the Engineer, 4-inch Y's shall be laid, with the branch tilted up at an angle of about 45°. These shall be furnished and laid without extra charge, up to an average of one in each 25 feet.

At points indicated by the Engineer, deep-cut house connections shall be put in according to the plans. The City shall pay for these the regular contract price.

In both ordinary and deep-cut house connections, the connection shall be closed by a vitrified stopper filled over with sand and lightly cemented.

(47) *Subdrains.* Wherever directed by the City, drain-tile subdrains of diameters directed by the Engineer shall be constructed. Each drain shall be laid just at one side of the sewer, at a depth below the sewer invert equal to the external diameter of the subdrain, *plus* three inches. Each joint shall be wrapped twice with a 4-inch strip of muslin at the time laid. The subdrains shall be laid carefully to line and grade; and wherever the Engineer may direct, 4-inch Y's stopped with brick shall be placed. In general, these Y's will be placed at the same points as the house connections on the sewer.

(48) *Subdrain Outlets.* Wherever directed by the Engineer, subdrain outlets shall be constructed, also as directed by the Engineer, and shall be paid for by the City on the basis of cost as determined by the Engineer, *plus* 10 per cent.

(49) *Measurements.* All measurements of sewers, subdrains, etc., shall be in horizontal lines from center to center of manholes and junctions.

MANHOLES AND OTHER APPURTENANCES

(50) *Manholes.* Manholes shall be constructed as shown on the plans and provided in these specifications, the exact location being indicated by the Engineer. All joints in the brickwork shall be shove joints, being filled full. Especial care shall be taken in forming the channels in the concrete bottoms, and wooden templates or half-sewer-pipe shall be used for this work, as directed by the Engineer. Drop manholes shall be constructed as shown on the plans without additional charge over the price bid, which shall be considered an average price.

(51) *Combined Manholes and Flush-Tanks.* Combined manholes and flush-tanks shall be constructed as shown on the plans and as specified for manholes in clause 50. The siphons shall be carefully set, and the cost of furnishing and setting shall be included in the price bid. The Contractor shall provide and set the water connection and bibbs from a point one foot outside the outside wall, on such side as the Engineer may direct.

(52) *Siphons.* Siphons shall be used as shown on the plans, guaranteed by the manufacturers, and tested after being set before acceptance. For the 8- and 10-inch sewers, 6-inch siphons shall be used, and 8-inch for all sewers larger than 10 inches.

(53) *Lampholes.* Lampholes shall be constructed as shown on the plans and provided in these specifications, the exact locations being indicated by the Engineer. The refilling shall be carefully placed and thoroughly rammed by hand in layers not exceeding 6 inches, around and to a distance of three feet each side of each lamphole. Special pains shall be taken to keep the lampholes truly vertical.

SPECIFICATIONS FOR SEWAGE-DISPOSAL PLANT

(54) *Grading.* All grading shall be done as shown by the plans. The bottom of the filter beds and bottom and sides of the septic tank shall be shaped to true surfaces by hand. All slopes shall be neatly dressed.

Should there be a deficiency of earth for the embankments, the Contractor may borrow from neatly-shaped borrow pits located on adjacent city land, where directed by the Engineer, leaving a smooth, uniform surface. Should there be surplus material, it shall be deposited along the edge of the lake, as directed by the Engineer.

(55) *Concrete Moulds.* The Contractor shall provide moulds of plank not less than two inches in thickness, thoroughly braced at intervals sufficiently close together to avoid distortion of the moulds. These planks shall be dressed on their edges and on the faces next to the wall. The moulds shall not be removed until the walls have become thoroughly set.

(56) *Facing of Concrete Walls.* In the construction of concrete walls, care shall be taken to keep all pebbles or stones away from the faces of the walls, so that the face shall be smooth and free from cavities or exposed stones or pebbles. The upper surface of the roof shall be floated with 1-2 thin mortar applied when the roof is made, and all cavities in other concrete surfaces filled and smoothed with 1-2 mortar.

(57) *Cement Wash.* On completion of concrete walls and floors, and after removal of the moulds and pointing up defects, all interior surfaces of floors and walls and roof, and the upper surface of the roof, shall be given two good coats of thin, neat Portland cement grout applied with a whitewash brush, time being left between applications for the first coat to set hard.

(58) *Alternating Siphons.* The alternating siphons shall be provided of the make shown on the plans, and set by the Contractor, strictly according to the directions of the manufacturer as given through the Engineer. Any imperfections affecting the working of the siphons when they are tested shall be corrected by the Contractor, who must guarantee their satisfactory working.

(59) *Filters.* The pebbles for the bottoms of the filters shall be screened clean of sand and properly graded, the 2-inch layer of fine pebbles being small enough to hold up the sand placed over it. All sand shall be clean and coarse, but the pebbles need not be screened out. In placing pebbles and sand, care shall be taken not to injure or disturb the drain tile, and the top surface of the sand shall very carefully be made level. Drain tile shall be laid carefully to line and grade.

(60) *Pipe-Laying.* All sewer pipe and cast-iron pipe shall be carefully laid to line and grade, with gaskets and tight joints, all as provided in the regular sewer specifications.

(61) *Sodding.* All earthwork slopes of the tank and filters shall be neatly sodded.

(62) *Bulkheads.* All bulkheads shown on the plans shall be constructed of Portland cement concrete, with moulds, and with care as to facing the same as provided for the concrete work of the septic tank.

(63) *Reinforcing.* The reinforcing shown on the plans is .... corrugated bars of not less than 50,000 lbs. per sq. in. elastic limit; but other forms of bars having equal elastic limit, equal net area, and a mechanical bond acceptable to the Engineer, may be used. The net area of any bars used must be increased to make good any deficiency in the elastic limit.

....

....

....

For brick sewers, the following specifications are suggested by Folwell in his book on *Sewerage:*

"For brick masonry in straight walls or sewers, none but whole, sound brick shall be used. For manholes, flush-tanks, and similar work, a limited number of half-brick may be used, not to exceed ⅓ of the whole in any case. Unless the Engineer direct otherwise, each brick shall be thoroughly wetted immediately before being laid. It shall be laid with a full, close joint of cement mortar on its bed, ends, and side at one operation. In no case is mortar to be slushed in afterward. Special care shall be taken to make the face of the brickwork smooth; and all joints on the interior of a sewer shall be carefully struck with the point of a trowel or pointed to the satisfaction of the Engineer. Where pipe-connections enter a sewer or manhole, "bull's-eyes" shall be constructed by laying rowlock courses of brick around them, the cost of such construction being included in the regular price bid for the sewer or appurtenances. Around pipe more than 15 inches in diameter, 2 rowlock courses shall be laid.

"Brickwork in sewers shall be laid by line, each course perfectly straight and parallel to the axis of the sewer. Joints appearing in the sewer shall in no case exceed ¼ inch in width. Sewers shall conform accurately in section and dimensions to the plans of the same. All inverts and bottom curves shall be worked from templates accurately set; the arches are to be formed upon strong centers accurately and solidly set, and the crowns keyed in full joints of mortar. No centers shall be drawn until the arch masonry has set to the satisfaction of the Engineer, and refilling has progressed up to the crown. They shall be drawn with care, so as not to crack or injure the work. The extrados is to be neatly plastered with cement mortar ½ inch thick, the arches being cleaned and wetted just before plastering. The end of each section of brick sewer shall be toothed or racked back; and before beginning the succeeding section, all loose brick at the end shall be removed and the toothing cleaned of mortar. All brickwork shall be thoroughly bonded, adjacent courses breaking joints at least ⅓ the exposed length of the brick.

"If there should be any distortion of the sewer before acceptance, this shall be corrected by tearing down and rebuilding. No local patching will be allowed, but when repairs are necessary a section shall be removed at least 3 feet long and including the entire arch, or the entire sewer if the defect is in the invert. Leakage of ground water into the sewer shall be similarly corrected, unless it can be prevented by calking the joints with oakum saturated in cement, with wooden plugs, or other material acceptable to the Engineer."

FORM OF PROPOSAL

——————, ————.

To the Mayor and Council of the Incorporated City of————, ————.

Gentlemen:

—— have carefully examined the plans and read the specifications prepared for your proposed sewage-disposal plant and sanitary sewers by————, Engineer, and —— agree to furnish all the materials and perform all the labor required for the completion of the proposed work for the following prices:

Item	Approximate Quantity	Unit Price	Total Price
Sewage Disposal Plant, complete			
Sewers, complete, including Y's, except subdrains, manholes, lampholes, and flush-tanks.			
18-inch			
15-inch			
12-inch			
10-inch.			
8-inch.			
Subdrains, complete			
10-inch.			
8 inch			
6-inch			
Deep-Cut House Connections, complete .			
Manholes, complete			
Combined Manholes and Flush-Tanks, complete			
Lumber Left in Trenches (per M., B. M.)			

All the above shall be strictly in accordance with the plans and specifications.

In case —— bid is accepted, —— agree to begin work within three weeks after the acceptance of —— bid, and to entirely complete the work on or before——————————————,————.

——— further agree to enter into contract and furnish bond satisfactory to the City Council within 12 days after acceptance of —— bid.

Respectfully submitted,

——————————

——————————

94. Form for Sewerage Contract. Besides plans and specifications, the sewerage Engineer is sometimes called upon to furnish a *Form of Contract* to be signed by the Contractor and the city representatives, though this, more properly, should be the work of the City Attorney. The following simple form of contract has been used successfully with specifications such as those given above:

This Article of Agreement, made this ——— day of ————— A.D., ——, by and between ——————, of ——————, ————, party of the first part, and the Incorporated City of ——, ——, acting through its Mayor and Council, party of the second part,

WITNESSETH:

The party of the first part agrees to furnish all material and perform all labor required for the entire completion of sanitary sewers, subdrains, and other appurtenances, on streets in the said City of ————, ———, as follows:

(NOTE: In this space place a list of the sewers included in the contracts by streets, giving the sizes on each street of both sewer and subdrain, and the points at which each size begins and ends.)

All the above sewers are to have manholes and other appurtenances as shown by the plans and specifications.

The party of the first part further agrees that all the above labor, and materials shall be strictly in accordance with the sewer plans and specifications prepared for the party of the second part by ——————, Engineer, said plans and specifications identified by the signatures of the parties hereto, being hereby made a part of this contract.

The party of the second part agrees to pay to the party of the first part for the above labor and materials, the following prices:

Sewers, complete, except subdrains, manholes, lampholes, and flush-tanks,			
	24-inch	$	per lin. ft.
	20 "		" "
	18 "		" "
	15 "		" "
	12 "		" "
	10 "		" "
	8 "		" "
Subdrains, complete,			
	24 inch		" "
	18 "		" "
	15 "		" "
	12 "		" "
	10 "		" "
	8 "		" "
Manholes, complete		$	each
Lampholes, complete			"
Combined Manholes and Flush-Tanks, complete			"
Flush-Tanks, complete			"
Lumber ordered left in trenches		$	per M. B. M.

The payments shall be made in——————————

——————and paid to the party of the first part in accordance with the provisions of the specifications, 2 per cent being reserved for one year to guarantee the work.

In Witness Whereof we have hereunto set our hands and seals the date and place first above mentioned.

———————

Party of the First Part

SEAL

The Incorporated City of ———, by

——————Mayor,

SEAL

Party of the Second Part

95. Form of Bond for Sewerage Contract. The Contractor for a piece of sewerage work is usually required to furnish to the City a bond, which is frequently for a sum equal to about one-half the amount of the contract. The simpler the form of the bond, the better. The following form has been used successfully:

BOND

Know all men by these presents, that we, ————————, of ——————————, ———, Principal, and

——————————————————————————————

——————————————————————————————

——————————————————————————————

Sureties

are held and firmly bound to the Incorporated City of ————, ————, in the penal sum of ———————————— Dollars (————————), lawful money of the United States of America.

Now, the condition of this obligation is that whereas the above-mentioned ——————, of ——————, ——, has entered into contract with the Incorporated City of ———, ——, dated ———., A. D. ——, to furnish all labor and materials required for the entire completion of about ——— feet of sanitary sewers, subdrains, and other appurtenances for the said City of ————, ————, now, if the said ——————, shall well and truly perform all the obligations of his said contract, strictly according to the terms thereof, then shall this bond be null and void, but otherwise it shall be and remain in full force and effect.

————————————
Principal

————————————
————————————
Sureties

CONSTRUCTION OF SEWERS

96. Letting the Sewer Contract. After the plans and specifications have been completed and accepted by the City, the next step will be to let the contract for the work.

First. The work should be advertised, if possible, three or four weeks in advance, in at least two good engineering or trade journals. It must often, by law, be advertised also in at least one local journal. For a form for the advertisement see pages 112 and 113.

Second. On the day and at the hour specified in the advertisements, the City Council meets to open the sealed bids which have been submitted on the blank "forms for proposals" furnished by the City for the purpose.

Third. If the bids are satisfactory, the contract is awarded to the *lowest responsible bidder.*

Fourth. A contract for executing the work in accordance with the plans and specifications, is signed by the Contractor and by the City.

Fifth. The Contractor furnishes a bond satisfactory to the City.

In all these steps, there is need of great care on the part of the city authorities to make sure that all provisions of the law are complied with, and they should be fully advised at all times by a competent attorney.

97. Organization of Engineering Force during Construction of Sewers. It is not common for the Consulting Engineer who prepares the sewerage plans and specifications, to be constantly on the ground or even in the city during construction. He makes only occasional visits for inspection and consultation.

The actual work of sewer construction is usually directly supervised either by the City Engineer, or by a *Resident Engineer* employed especially for this purpose.

It will be necessary for the resident engineer in charge of the construction of a sewerage system of some magnitude, to have an office and an adequate equipment of drafting apparatus, surveying instruments, etc. He will have employed under him:

Draftsmen and clerks, in the office.
Instrument men and rodmen, to do the surveying.
Inspectors, constantly on all work, to insure its being properly executed.

The resident engineer himself will supervise these employees, visit all parts of the work frequently, and constantly exercise general supervision over all its features.

98. Laying Out the Sewer Work. After checking up the benchmarks on the original survey, it will be necessary for the engineering force to stake out the sewers, keeping somewhat in advance of the actual construction.

The stakes are usually placed a uniform distance to one side of the true line, so as not to be disturbed by the digging of the trench. This distance, and the side on which the stakes are placed, should be the same for all parts of the work, to avoid confusion and mistakes.

The stakes should usually be set about 25 feet apart.

The manholes should usually be located first, in accordance with the profile sheets; and the sewers should be run as straight lines, center to center of adjacent manholes. All discrepancies from the original measurements should each be adjusted, if possible, between the two manholes between which each was found; and such discrepancies should not be carried on to affect all the rest of the work.

There are two methods of giving grades for sewers.

(1) The best method is to set the grade stakes nearly flush with the surface, at a uniform offset to one side of the trench, ascertaining

the distance of the top of each stake above grade by carefully checked levels. By measuring from these stakes, a grade cord, supported on cross-frames every 25 feet, is stretched parallel to the grade line of the sewer, over its center line. For this method of giving grades, see Fig. 40.

(2) Another method is to set grade stakes at the bottom of the trench. This method is adapted only to very large sewers.

99. Trenching and Refilling. Sewer trenching and refilling may be done either by machines or by hand. *Excavating Machines* for sewers are of two types:

(1) *Machines which themselves do the excavating.* These are just coming into use, and are becoming more and more successful.

(2) *Machines which simply carry away the excavated material,* usually dumping it over the completed sewer further back. This type has the advantage of not piling up the dirt in the busy street. It carries, on overhead cableways or trestles, buckets which can be lowered into the trench, and in which the excavated material is placed by hand.

Machines of both types are suited best to comparatively extensive work; and under favorable conditions they lessen the cost materially.

Most sewer trenching, however, is done by *hand.* For such work the men are organized in gangs, the number of men in each gang varying from 20 to 80. Each gang has a foreman, and a water boy, and sometimes a sub-foreman. A pair of pipe-layers may work with each gang, or, if the trench be deep, one pair of pipe-layers may work part of the time with one gang and part with another.

The details of sewer trenching and refilling as ordinarily carried out, are specified quite fully in clauses 38, 40, and 41 of the sample sewer specifications given in Art. 93 (which clauses now read carefully). All details there specified should be enforced by the Inspector and the Engineer.

In clause 41, Art. 93, referred to above, the method specified for compacting the refilling is by flooding with water. While this is the cheapest method, where the water is available, and while it gives good results if properly done, it may be found necessary sometimes, in the case of paved streets, to adopt the more expensive method of *tamping.* For thorough tamping, there should be from 1 to 2 men tamping, to 1 shoveler, and the rammers used should weigh 4 to 6 pounds each. The soil refilled should be moistened if dry, and should be tamped in about 4-inch layers. It is possible by very thorough tamping to compact the soil more thoroughly than by flooding.

100. Sheathing. Except for shallow ditches in very solid earth, it is usually necessary to brace the sides of sewer trenches to prevent their caving in. Such bracing is called *sheathing*. The most common methods of sheathing are illustrated in Fig. 40.

The horizontal members of the sheathing are called ***rangers***, and the rangers are held the right distances apart by *sewer braces* of wood or iron. The iron braces are shown in Fig. 40. The rangers are usually about 12 feet long. Behind the rangers are placed the vertical planks of the sheathing, either a few feet apart in firm material, forming *skeleton sheathing*, or in contact with each other in caving material, forming *close sheathing*. The sheathing plank are 2 inches thick and are usually about 10 feet or 12 feet long. The rangers may be 2-inch planks in favorable soil, or 4 by 4 or even 4 by 6 inches in poor soil.

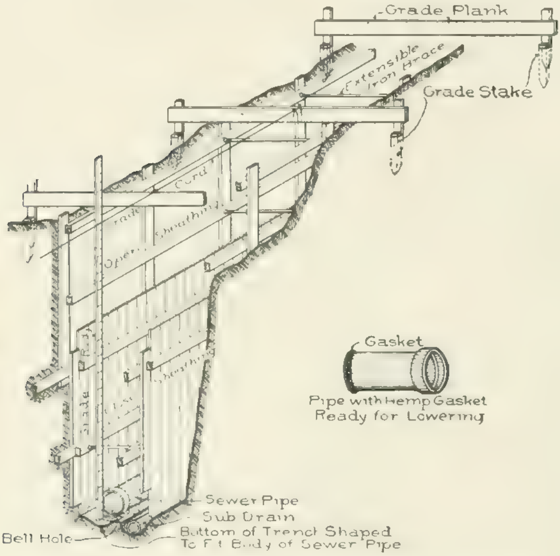


Fig. 40. Diagram Showing Construction of Pipe Sewer.

The sheathing plank are usually driven by hand, with wooden mauls.

Sometimes, for large sewers, heavy *sheet piling* may be driven by pile-drivers, to take the place of ordinary sheathing.

Ordinary sheathing is removed from the trench as the refilling proceeds. In case of special danger to near-by water mains, conduits, or foundations, on account of possibility of the banks caving before the refilling is finally settled, the Engineer may order the sheathing to be left permanently in the trench. In such case, the Inspector makes record of the exact amount of lumber left in the trench, and the City pays for it.

101. Pipe-Laying. The pipe-laying is usually done by two men, though, with large pipes, another may be needed. These men excavate the last few inches of the trench, as well as lay the pipes.

The laying of every pipe, and the making of every joint, should be carefully watched by an Inspector, who should faithfully enforce the specifications.

For specifications for pipe-laying, see clause 45, Art. 93 (which clause now read carefully).

All the sewer pipe should be carefully inspected before being used, and those pieces rejected which do not meet the specifications. See clause 25, Art. 93. The Inspector should see that no rejected or poor pipe is used.

The Inspector should see that every pipe is laid exactly to grade by measurement from the grade cord (see Fig. 40).

The Inspector should also see that house-connection Y's are placed opposite each lot on each side of the street, at the proper points; and he must exactly locate each such connection by measurements fully recorded in his notebook.

102. Construction of Brick Sewers. For specifications for the construction of brick sewers, see reference to Folwell in Art. 93, p. 122. (Read carefully.)

The construction of a brick sewer is shown in Fig. 41.

It will be the duty of the Inspector to inspect all brick before they are used, rejecting the poor ones, and to fully enforce the specifications for construction. He must also see that the templates are set truly to line and grade, that the house connections are set at the proper places and heights, and accurately located in his records.

In the case of large brick sewers, more trouble is to be expected with foundations than in the case of pipe sewers. Sometimes soft soil or quicksand may make it almost impossible to shape the material in the bottom to fit the outside of circular sewers. In such cases, special foundations, such as shown in Fig. 20, may have to be put in through the treacherous material. Other forms of special foundations are often used.

The Engineer should make full record of all such features of the work.

103. Records of Sewer Construction. *Daily Reports.* The resident Engineer in charge of the construction of a sewerage system, should require, from all members of his engineering force, daily reports, on suitable blank forms, showing the exact work on which each was engaged. Another set of exact reports should show the work accomplished by the Contractor each day, and the materials and labor used on each part of the work.

Data of Sewer Construction. The information from these daily reports should be entered in a permanent book, showing all features of the progress of the work, and giving data for itemized estimates of the cost.

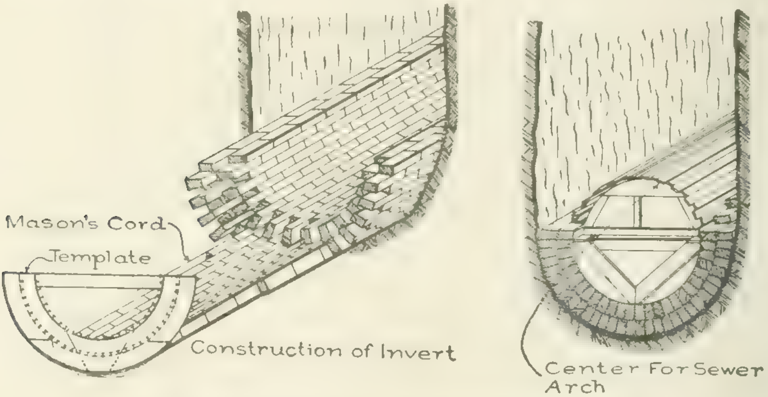


Fig. 41. Diagrams Showing Construction of Brick Sewer.

Sewer Record Book. In another permanent book, a complete, final record of all the sewers should be entered.

On the left-hand page may be given in order the numbers of the stations of the sewer survey, running from the bottom to the top of the page, together with the surface elevations, the grade elevations, and the rate of grade.

The exact character of the soil should also be shown, with exact levels for computing any rock excavation. Notes should be made of the level and amount of any ground water encountered.

On the right-hand page should be made a large-scale sketch of the sewer, showing its exact location with reference to the street lines

Large Concrete Sewer in Aramingo Canal.

Wakeling Street Concrete Sewer, 16 ft. by 10 ft. 6 in.

TWO VIEWS OF SEWERS IN THE CITY OF PHILADELPHIA, PA.

Courtesy of Geo. S. Webster, Chief Engineer, Bureau of Surveys, Dept. of Public Works

and the lot lines, and the exact location of manholes and other accessories. This sketch should also show the location of all house connections, with exact measurements (such as the station and *plus* of each connection) by which to locate all such connections.

On the right-hand page may also be entered the exact limits of sheathing left in trenches, and the amounts of lumber in such sheathing, as well as the exact limits and character of all special sewer foundations, of changes of grade where other conduits are crossed, and of all other extra work.

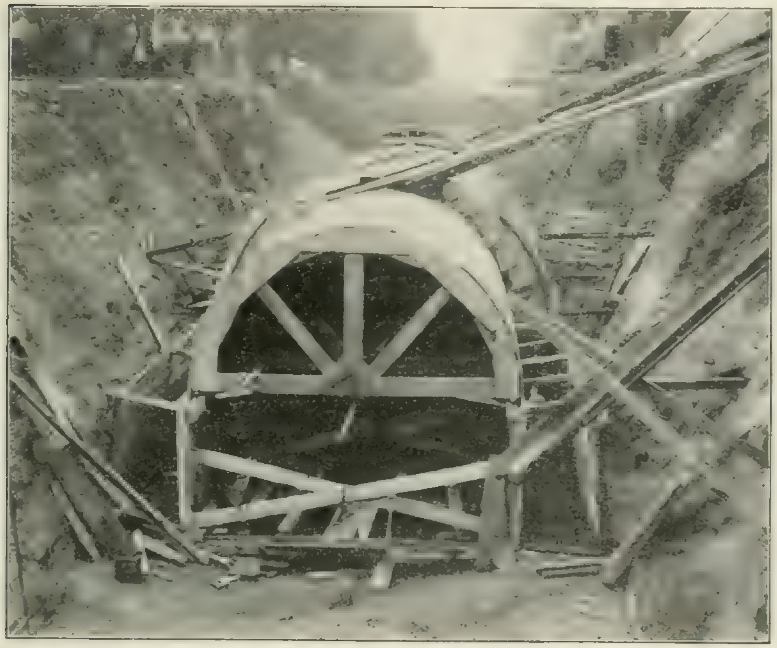


Fig. 42. Construction of Dry-Run Concrete Sewer, Waterloo, Iowa.

Final Sewerage Map and Profiles. On completion of the system, the resident Engineer should make a complete final sewerage map, and complete final profiles of all sewers, both corrected by any changes from the original plans adopted during construction.

Plat of Sewer Connections. For small towns, at least, large-scale plats of the different streets should be prepared, showing the exact location of all house connections.

MAINTENANCE OF SEWERS

104. Sewerage Systems should be Carefully Maintained in Good Condition. Too often it appears to be considered that when a sewerage system is completed all further care of it can be neglected with impunity. This is a great mistake. The sewerage system may become a source of danger to the public health, instead of a means of safety, unless it is given proper care and attention.

105. Sewer Ordinances, Permits, and Records. Every city having sewers should pass a carefully prepared *Sewer Ordinance*, prescribing in detail the conditions under which citizens are permitted to use the sewers.

One provision of the Sewer Ordinance should be, that all property owners desiring to make sewer connections shall first secure a *Sewer Permit.* For this and for the application for it, blank forms are provided, which are to be filled in by the applicant, giving full description of the connection. The permit will require the work to be done according to the city regulations.

Every house sewer should be connected with the sewer at a regular house connection. No cutting into the sewer whatever should be permitted, as there is great danger of such cutting ruining the sewer.

Full *Sewer Records* should be kept by the proper city officers, showing full details of all connections with the sewers. This is too often neglected, to the great detriment of the City, which finds itself without means of ascertaining what people or how many are using the sewers, and perhaps putting injurious substances into them.

106. Plumbing Regulations, Tests, and Licenses. The city should also prescribe by ordinance strict *Plumbing Regulations*, setting forth in full detail the requirements for good plumbing (see Articles 76 to 81 inclusive). All property owners should be required to do all plumbing in strict accordance with these regulations.

The work should be carefully *inspected and tested* by a City Inspector, to see that it fully complies with the ordinance. The *water test* is applied by stopping up the outlets of the soil-pipe and of the various fixtures, and filling the pipes with water, when defects will be shown by leaks. In the *smoke test*, the pipes are blown full of smoke; and in the *peppermint test*, oil of peppermint is poured into them. In neither case must it be possible to detect any of the odor in the interior of the house.

Plumbing regulations usually require that plumbing shall be done only by plumbers holding *plumbers' licenses* granted by the City. The proper city officers have blank forms for making applications for such licenses, as well as for the licenses themselves. The plumber making application for a license should be required to show proof of proficiency, and should be placed under bond to comply fully with the sewer ordinance and the plumbing regulations, and to protect the City from damages on account of his work. The plumber may also be made subject to fines for violating the sewer ordinance and regulations, and to revocation of his license.

107. Regular Sewer Inspection. In sewer maintenance, besides the work of granting sewer permits, and inspecting house plumbing and the making of connections with the sewers, the entire sewerage system should be gone over regularly and carefully by a Sewer Inspector, once every two weeks if possible.

The Inspector, in this work, should open all manholes and lampholes, and carefully examine the sewer to make sure that it is keeping clean, well-ventilated, and reasonably free from offensive odors. He should also examine carefully the working of all flush-tanks, to make sure that they are operating satisfactorily. He should also examine all catch-basins, to make sure that they are cleaned frequently enough.

Small defects found on these periodical inspections should be remedied at once, and full notes made of more extensive work found to be necessary.

108. Flushing and Cleaning of Sewers. In many sewerage systems, it is found impossible to prevent absolutely the formation of deposits in the sewers, which must then be removed by hand-flushing, or by direct cleaning of the sewers.

Flushing is ordinarily preferred to hand-cleaning methods where the water for the purpose is available, and where it is readily possible to remove the deposits in this way. For the most common methods of hand-flushing, see Art. 25.

In hand-cleaning, large sewers may be entered by the workmen themselves to remove the deposits. In small sewers, lines are often floated down from one manhole to the next below; and by means of these lines, various cleaning devices are dragged through the sewer, or back and forth in it, to remove the deposits. Sometimes, for small sewers, a ball, a little smaller than the sewer, with a line attached to haul it back in case of stoppage, is allowed to float down the sewer, from manhole to manhole. The sewage is dammed back by it, and spurts out on all sides under pressure, thus scouring and cleaning the sewer.

For large sewers, discs or gates, traveling on carriages, or boats, may be used, working on the same principle. Many forms of such apparatus have been devised. A notable example of the use on a large scale of traveling sewage-scouring gates is in connection with the Paris sewers, Fig. 24.

109. Cleaning of Catch-Basins. In Art. 27, catch-basins were described; and it was stated that unless they are frequently cleaned they become filled with filth and soil and debris from the street, and fail utterly in their purpose, which is to keep such materials out of the sewers. Moreover—which is still worse than this—uncleaned catch-basins are unsanitary, and are sources of foul odors. Hence catch-basins, when used, should be regularly cleaned, and the City should have a regular arrangement for this work, and should provide labor-saving apparatus for the work, such as hoisting apparatus or special pumps for lifting the material from the catch-basins to the wagons.

SEWAGE DISPOSAL

110. Sewage Disposal Definitions. There is some confusion as to the meaning which should be given to the term *sewage disposal*, there being a tendency to treat it as meaning the same thing as sewage purification. It seems wise to hold more closely to the strict meaning of the words.

Sewage Disposal refers to the means adopted for disposing of, or getting rid of, sewage.

Sewage Purification is treatment of sewage to rid it of its foul impurities and render it harmless.

111. History of Sewage Disposal. In ancient times the only method used for disposing of the sewage of cities was to empty it into some stream or other body of water. This method, called *dilution*, is still in use more than any other, owing to its cheapness. From time immemorial, however, the cesspool has been used to receive the sewage of private houses, and we now know that a considerable percentage of purification is effected in cesspools, by bacterial action of the same nature as that now utilized in the modern *septic tank*.

By the middle of the nineteenth century the construction of sewerage systems had increased to such an extent that the streams in thickly settled countries became badly polluted by sewage, and it became necessary to turn attention to methods of purification. In England, especially, much work was done, and much success was attained with purification by *land treatment*, or *irrigation*. A great deal of work was done, also, in the same country, with methods of *chemical treatment*.

In 1887, the Massachusetts State Board of Health in this country began extensive experiments in sewage disposal, which soon demonstrated the great value of *intermittent sand filtration*.

About 1896 the *septic tank* came into prominence in both England and the United States. At about the same time, also, the *contact bed* was developed in England, and soon after copied in the United States, where it did not prove much of a success.

Within the last few years, *sprinkling filters* have come into use for conditions which require a large amount of sewage to be purified on a small area.

There is, at present, much activity in sewage purification, both as regards actual construction of plants, and as regards continued experimentation and research.

112. Importance of Sewage Disposal. The importance of sewage disposal at the present time is very great. All cities and nearly all villages find sewers indispensable, yet neither law nor justice will permit them to cause damage to the property or danger to the health of other communities or persons by discharging in their midst foul, unpurified sewage. More and more sewage purification plants are being required in connection with sewerage systems. Communities which disregard the rights of others in this respect are more and more finding that they must face damage and injunction suits.

113. Variable Composition of Sewage. Prior to taking up methods of sewage purification, it will be necessary to learn something about the composition of sewage; and the first thing to be noted is that the composition is extremely variable. Even in the same sewer, sanitary sewage is much stronger in the daytime, when the flow is heavy, than at night, when the flow is light. In fact, the composition will vary from minute to minute. Manufacturing and storm sewage, also, vary greatly in character at different places and times.

A sample of sewage for analysis, therefore, should consist of a mixture of several small amounts, taken systematically at different times, with great care to get a truly average portion each time.

114. Chemical Analyses of Sewage. Chemical analyses of sewage are *indirect*—that is, it is impossible to determine *directly* the amount and kind of polluting organic matter. Hence the chemist determines a number of things, harmless in themselves, from which he can judge in a general way of the amount and kind of the polluting organic matter. The things usually determined in a chemical analysis, and their meanings, are as follows:

Chlorine. This is in the form of common salt, in itself harmless. In sewage it indicates the strength of the original sewage, but not whether or not it has been purified.

Albuminoid Ammonia. This indicates the amount of undecayed organic matter, containing nitrogen, in the sewage.

Free Ammonia. This indicates the amount of decaying organic matter, containing nitrogen, in the sewage.

Nitrites. These indicate a further step in the process of decay (which is also the process of purification).

Nitrates. These indicate purified organic matter, containing nitrogen.

Oxygen Consumed. This gives an indication of the total unoxidized organic matter in the sewage.

Solids on Evaporation. These indicate the total foreign matter in the sewage, whether organic and therefore dangerous, or mineral and therefore probably not dangerous.

Loss on Ignition. This is intended to indicate the total organic matter which can be burned out of the solids on evaporation by heating them to a red heat; but if the water has a high mineral content, the loss on ignition does not appear to give a very reliable indication of the organic matter.

115. Bacterial Analyses. Bacterial analyses of sewage, as usually made, are quite simple, consisting simply of determinations of the total number of bacteria, without regard to their different kinds, in one cubic centimeter of the sewage. Most of these bacteria are perfectly harmless; but where many bacteria can flourish, disease germs might at any time flourish also.

116. Sample Analyses of Sewage. In Table XIV are presented a few random samples of chemical and bacterial analyses of sewage from sewage purification plants.

The sewage analyzed at Fort Des Moines was weak; that at Ames, stronger, but hardly of average strength; and that at Mt. Pleasant, of about average strength.

For each place, the *raw sewage* represents the *unpurified* condition; the *septic tank effluent*, the *partially purified* condition; and the *filter effluent*, the *purified condition* of the sewage. The purification at Fort Des Moines and at Ames was very good, and that at Mt. Pleasant poor.

TABLE XIV

Sample Analyses of Sewage from Purification Plants

Parts per 1,000,000

Place and Kind of Sewage	Chlorine	Albuminoid Ammonia	Free Ammonia	Nitrites	Nitrates	Oxygen Consumed	Solids on Evap.	Loss on Ignition	Bacteria per Cu. C M.
Ft. Des Moines, Ia.									
Raw Sewage	16.0	6.0	2.5	Trace	0	20.6	490	130	713,000
Tank Effluent	18.0	6.5	8.5	0	0	15.9	524	166	582,000
Filter "	16.0	0.4	0.5	Trace	12.0	6.3	460	120	1,100
Ames, Iowa.									
Raw Sewage	60.0	7.5	20.0	0	0	96.2	950	230	495,000
Tank Effluent	61.0	5.0	21.0	0	0	99.6	978	226	849,000
Filter "	80.0	0.6	0.1	Trace	4.8	20.2	1,150	250	900
Insane Asylum Mt. Pleasant, Ia.									
Raw Sewage	150.0	5.0	28.0	0	0	64.6	2,412	440	1,680,000
Tank Effluent	157.0	4.0	28.5	0	0	105.0	2,072	278	1,210,000
Filter "	150.0	4.0	16.0	Trace	0	25.3	2,062	270	519,000

117. Methods of Sewage Purification. The principal different methods of sewage purification are as follows:

Irrigation. In this method, the sewage is used to irrigate crops, on a *sewage farm.* The method is very efficient with sufficiently porous land; but the large area required, and the difficulty experienced by cities in successfully operating sewage farms, restrict the use of this method in the United States almost entirely to the arid regions, where the soil requires irrigation anyhow, and where water for irrigation is scarce and valuable. The method is also used to a considerable extent in Europe, notably in Paris, in Berlin, and in Birmingham and several other English cities.

From 5,000 to 25,000 gallons of sewage per acre per day may be purified by irrigation, depending upon the porosity of the soil. Porous, sandy soils are the best. A very high degree of purification can be attained by irrigation.

Chemical Precipitation. In this method, certain chemicals (usually lime, alum, or iron) are added to the sewage, to precipitate the suspended organic matter, in *precipitation tanks.*

On account of the great cost of the chemicals and labor required, and the great difficulty of satisfactorily disposing of the large amount of *sludge* precipitated, the chemical treatment of sewage is now very seldom adopted, though it was quite popular twenty-five years ago. Only 25 to 50 per cent efficiency can be attained.

Settling Tanks. These are for a preliminary treatment, sometimes given sewage before filtering it, in order to get rid of part of the solid matter in the sewage, which otherwise might tend to clog the filters. Some bacterial purification also occurs in settling tanks.

Septic Tanks. These tanks are larger than settling tanks, and hold the sewage and sludge (or solid matter settling in the tank) long enough for bacteria to act and to effect partial purification. This is also, usually, a treatment preliminary to filtration. For further discussion, see Art. 120.

Intermittent Sand Filtration. In this method the sewage is discharged *intermittently,* upon the surface of sand filters. The sewage may or may not have first a preliminary treatment in tanks. This is a very efficient method, and is one of the most common at present in use. For further discussion, see Art. 122.

Contact Beds. These are filters of coarse material (say ½-inch to one-inch size) with water-tight walls and bottoms, which are alternately filled with sewage, allowed to stand full for a certain *contact period,* emptied, and allowed to stand empty for a certain *aeration period.* This method was quite popular a few years ago, but proved inefficient and troublesome in many places, and is now largely out of favor.

Sprinkling Filters. These filters, also, are made of coarse material; but the sewage is *sprinkled* continuously upon the surface, so as to trickle slowly over the pieces of filter material, the outlet drains being left open all the time. This method has lately come into favor as requiring much less area than sand filters, though not so efficient, and is now the method commonly recommended where circumstances render it advisable to adopt high rates of filtration, though at some cost of efficiency. For further discussion, see Art. 123.

118. Methods of Sewage Disposal Now Most Commonly Used. These are:

(*a*) *Dilution,* where purification is not required.

Where, on the other hand, purification is required, the usual methods are:

Preliminary Treatment by
  (*b*) *Septic Tanks,* or by
  (*c*) *Settling Tanks,*
followed by
Final Treatment by
  (*d*) *Intermittent Sand Filters,* or by
  (*e*) *Sprinkling Filters.*

119. Dilution. In this method of sewage disposal, the sewage is simply discharged into the ocean, or into a lake, a river, or other body of water, dilution by the water being relied upon to prevent the creation of a nuisance by the sewage. In the water, bacterial processes of purification by decay start up, which, after a sufficient time, break up the organic compounds in the sewage, and finally render it harmless.

Dilution has, over other methods, the one advantage of *cheapness;* and this is still sufficient to decide in its favor in the majority of cases, when the body or stream of water utilized is sufficiently large to prevent a nuisance. Chicago furnishes a most notable example of large expenditure to secure sufficient dilution for its sewage, having already expended over $50,000,000 in building the great "Drainage Canal" (see Fig. 5) to take water from Lake Michigan for this purpose.

Most cities in the United States dispose of their sewage by dilution, and the sewerage Engineer should always give the possibilities along this line full consideration. He will usually advise adoption of the method (at least for the present) where it is cheaper, and where it is certain that a nuisance will not be created, nor serious damage or danger to other communities or persons result.

120. Septic Tanks. These are simply large tanks, in which the sewage is held long enough for most of the solid matter to settle out, and long enough for certain species of bacteria to act both upon the liquid sewage and the sludge.

Theory of Action of Septic Tanks. The bacteria which flourish in septic tanks belong to the general class known as *anaërobic* bacteria. This term means bacteria which do not need the oxygen of the air to live. In ordinary decay of organic matter, anywhere, both these and other bacteria are the active agents, and some of the germs are found in all sewage. In septic tanks the conditions are favorable to the enormous development of anaërobic bacteria, since the sewage is still, and there is usually no free oxygen in the sewage, and since, moreover, there is abundance of the organic matter which forms the food of these particular bacteria. In septic tanks, the bacteria act upon the sludge, to partially liquefy it; and they also act upon the organic matter in both the solid and the liquid state, to partially purify it.

Efficiency of Septic Tanks. In practice it is found that septic tanks remove only 25 to 50 per cent of the organic matter in the sewage, and that the bacteria in the effluent are very high in number (see Table 14).

Essentials of Septic Tanks. The only essentials of septic tanks are: (1) That the sewage shall be introduced and taken out in such a way as to insure a uniform distribution through the entire cross-section as it passes through the tank; (2) that the outlet shall be so arranged that neither the floating scum on top nor the layer of settled impurities at the bottom shall be permitted to escape; (3) that the tank shall be large enough to hold the sewage sufficiently long for the bacterial action, but not so long that the bacterial action proceeds too far, which might cause excessive offensive odor, and unfit the sewage for filtration. A capacity of 12 to 24 hours' flow of sewage is usually considered to be the proper size.

Septic tanks are commonly used preliminary to filtration of the sewage.

In Fig. 43 is shown the general arrangement of a typical sewage-disposal plant for a small city. It consists: (*a*) of a *septic tank* of 80,000 gallons' capacity, in which the sewage is first received; (*b*) of *two sand filters*, each containing 13,000 sq. ft. of area, through which the sewage is filtered after first passing through the septic tank; and (*c*) of a *sludge area* provided for drying the sludge after it is taken from the septic tank, preparatory to hauling it away.

Usually *a septic tank should be nearly emptied of sludge about once a year.* The sludge area may be simply a prepared earth area, on which the sludge can stand and drain. Usually the sludge area is at a lower elevation than the bottom of the septic tank, and the sludge is allowed to run out upon it through an iron pipe, by gravity. Otherwise a centrifugal pump may be provided for pumping out the tank.

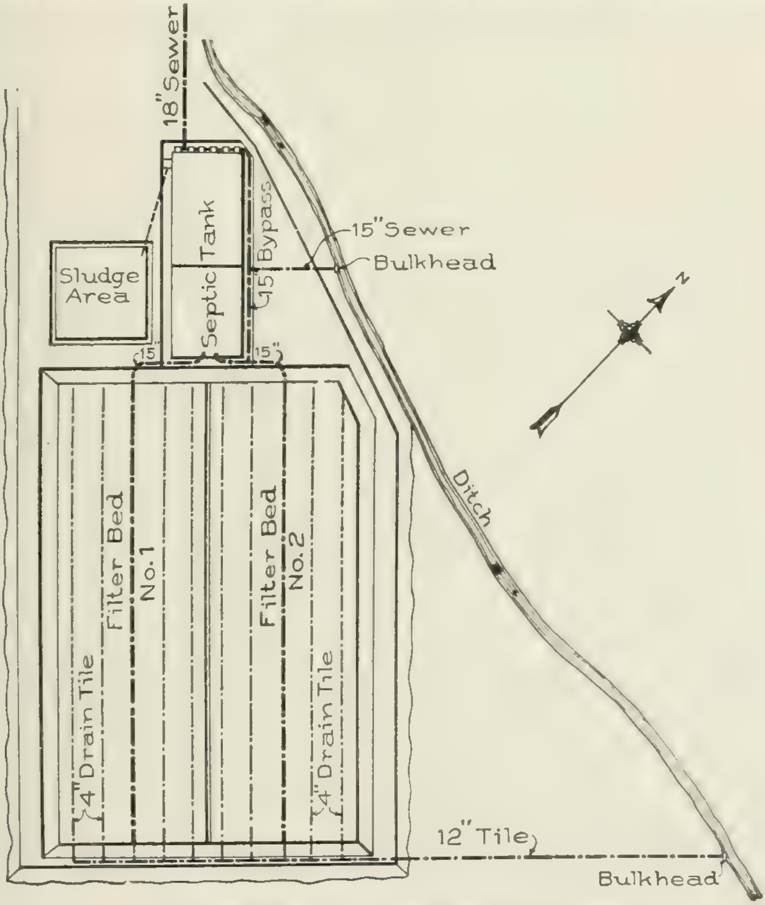


Fig. 43. Plan of Sewage Disposal Plant Carroll, Iowa.
Original Scale, 1 Inch = 40 Feet.

In Fig. 44 detailed plans are given of the septic tank whose general location is shown in Fig. 43. The tank shown is made entirely of concrete, reinforced with steel rods. Even the flat roof is 5 inches of reinforced concrete. It consists of two parts as shown, a *septic tank proper*, and a *dosing chamber.*

The *septic tank proper* holds 60,000 gallons, and is divided longitudinally into two compartments, one twice as large as the other, to permit the size used to be varied to suit the amount of sewage flowing. Entering at the left-hand end of the tank, as shown in Fig. 44, the sewage passes into the tank through 6 openings, and, striking a baffle wall, the currents are forced down and spread out to give a uniform distribution of the flow. At the opposite end of the septic tank proper, the sewage must pass up under another baffle wall, and then flows into the dosing chamber over six weirs, opposite the six inlets. In falling from the weirs the sewage is aërated.

The *dosing chamber* holds 20,000 gallons, and is provided with two *alternating siphons*, one connected with each sand filter bed.

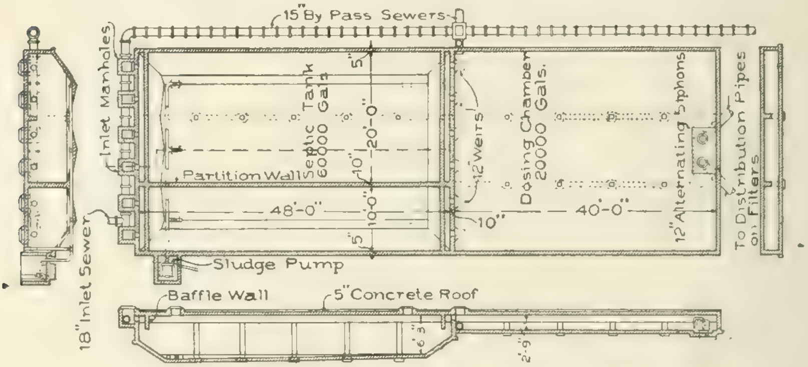


Fig. 44. Plan and Sectional Elevation of Septic Tank, Carroll, Iowa. Original Scale, ¼-Inch = 1 Foot.

These are similar to the flushing siphons described in Art. 24, but are so arranged that they discharge in rotation. Whenever the dosing chamber fills to the high-water line, one of these siphons discharges the entire 20,000 gallons within a few minutes upon the surface of its filter. The distribution of the sewage upon the filters is thus automatic. There are other types of automatic distributing apparatus. Those having moving parts are more liable to get out of order than are siphons.

In Fig. 45 is given a view of the above concrete septic tank during construction.

Many other designs of septic tanks are used successfully. In some, a house is built over the sewage.

In Fig. 46 is given an interior view of the dosing chamber of one of the septic tanks at Ames, Iowa. The alternating siphons appear in the view.

121. Settling Tanks. Settling tanks differ in no essential way from septic tanks, except in point of size. Settling tanks are made much smaller than septic tanks, and hence do not afford time for so complete bacterial action, and must be emptied of sludge frequently, instead of only once a year. Hence a complete, convenient, and inexpensive means of cleaning out and drying the sludge is even more important than in the case of septic tanks.

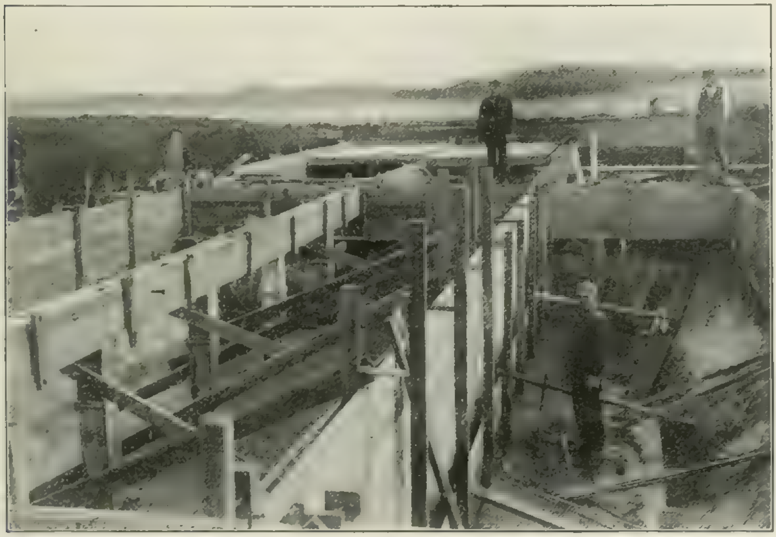


Fig. 45. Septic Tank at Carroll, Iowa, under Construction.

122. Intermittent Sand Filters. With the exception of irrigation under favorable conditions, intermittent sand filtration furnishes the most efficient means of purifying sewage which is in common use. In this method, the sewage is discharged *intermittently* upon the surface of sand filters 2½ to 4 feet deep. The area of filter needed will usually be one acre to every 100,000 to 150,000 gallons of sewage per day. Any good, clean, coarse mortar sand will answer for the filter. The filter is usually underdrained by lines of agricultural drain-tile placed 5 feet to 20 feet apart; and the bottom of the bed is often covered with a layer of graded pebbles or broken stone, to make the drainage more nearly perfect.

Theory of Action of Sand Filters. In each cubic foot of sand are many millions of particles of sand, whose aggregate surfaces may amount to thousands of square feet, and these particles have many millions of intervening pores. Upon the surfaces of the sand grains, the bacteria of purification become established in innumerable billions, and they work upon the organic matter in the sewage slowly trickling past them. In sand filters the bacteria are of the general class known as *aërobic* bacteria, or those which require oxygen to live. Hence the application of sewage must be *intermittent*, to allow each dose to penetrate down into the sand out of sight, and draw air into the pores after it, before the next dose is applied.

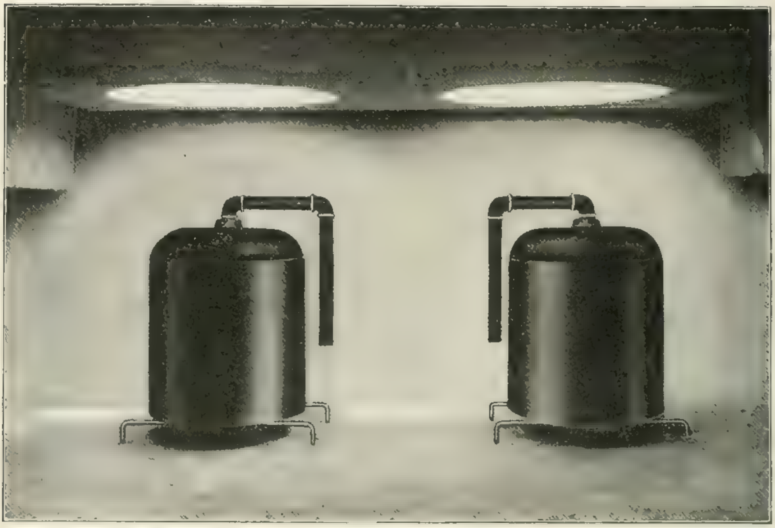


Fig. 46. Interior of "Dosing Chamber" of Septic Tank at Ames, Iowa, Showing "Alternating" Siphons.

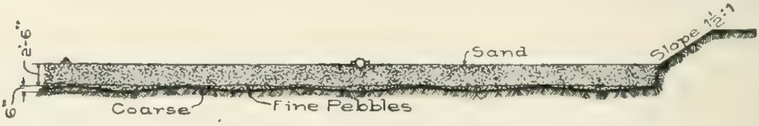


Fig. 47. Cross-Section of Intermittent Sand Filter.

Efficiency of Sand Filters. Sewage-disposal plants having sand filters should remove 85 to 98 per cent of the organic matter from the sewage, and 98 to 99.8 per cent of the bacteria.

In Fig. 47 is given a cross-section of one of the intermittent sand filters shown in Fig. 43. Each of these filters is 200 feet long by 65 feet wide, by 2 feet 9 inches average depth. A large sewer-pipe from one of the alternating siphons passes down the center on top of each bed, with 4-inch openings each side every 10 feet for distributing the sewage evenly over the surface. The sand is 2 feet 6 inches deep, and is underlaid with a layer of graded pebbles 0 to 6 inches deep. Lines of 4-inch agricultural drain-tile 13 feet apart are provided to remove the filtered sewage.

In Fig. 48 is given a view of a similar sewage filter under construction. In this case considerable grading had to be done out into a lake to get room for the filters.

Fig. 49 is a view of a completed plant, consisting of a septic tank, with intermittent sand filters. The purified effluent from this plant is as clear and odorless as spring water.

123. Sprinkling Filters. These are made of coarse material, say ⅓ inch to 1 inch in size. Sewage flowing upon such coarse material would pass through the large pores too quickly to receive much purification. Hence the sewage must be sprinkled upon the top surface in drops to insure its simply trickling over the surfaces of the pieces of filter material. There are many devices for distributing the sewage in this way, including, principally, traveling perforated arms, and spray nozzles. All the devices need constant, intelligent care to keep them in order.

The material of which sprinkling filters are made may be pebbles, crushed stone, crushed coke, or any hard, durable material, crushed to the proper size.

Sprinkling filters possess the great advantage over other types, of the very high rate of filtration possible, and the small filter area consequently required. Rates of 1,000,000 to 2,000,000 gallons per acre per day have been proposed. They are not so efficient, however, as sand filters.

Theory of Action of Sprinkling Filters. In the case of sprinkling filters, owing to the coarseness of the pieces of filtering material, and the fact that the sewage is applied in drops, and runs over the pieces of the filtering material in films, without filling the pores, sufficient air remains constantly in the pores of the filters to keep alive the aërobic bacteria of purification. Hence the application of the sewage

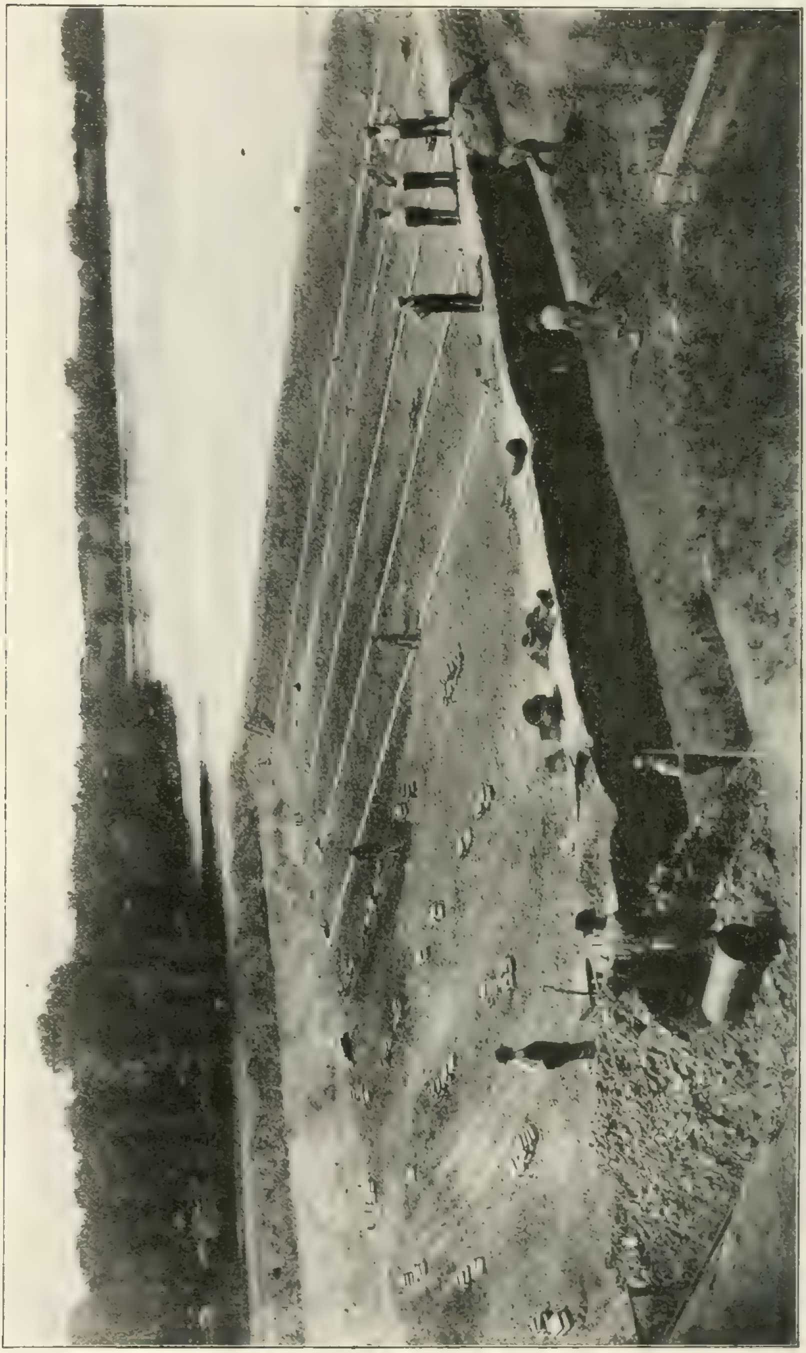


Fig. 48. "Intermittent" Sand Sewage Filters at Fairmont, Minn., under Construction.

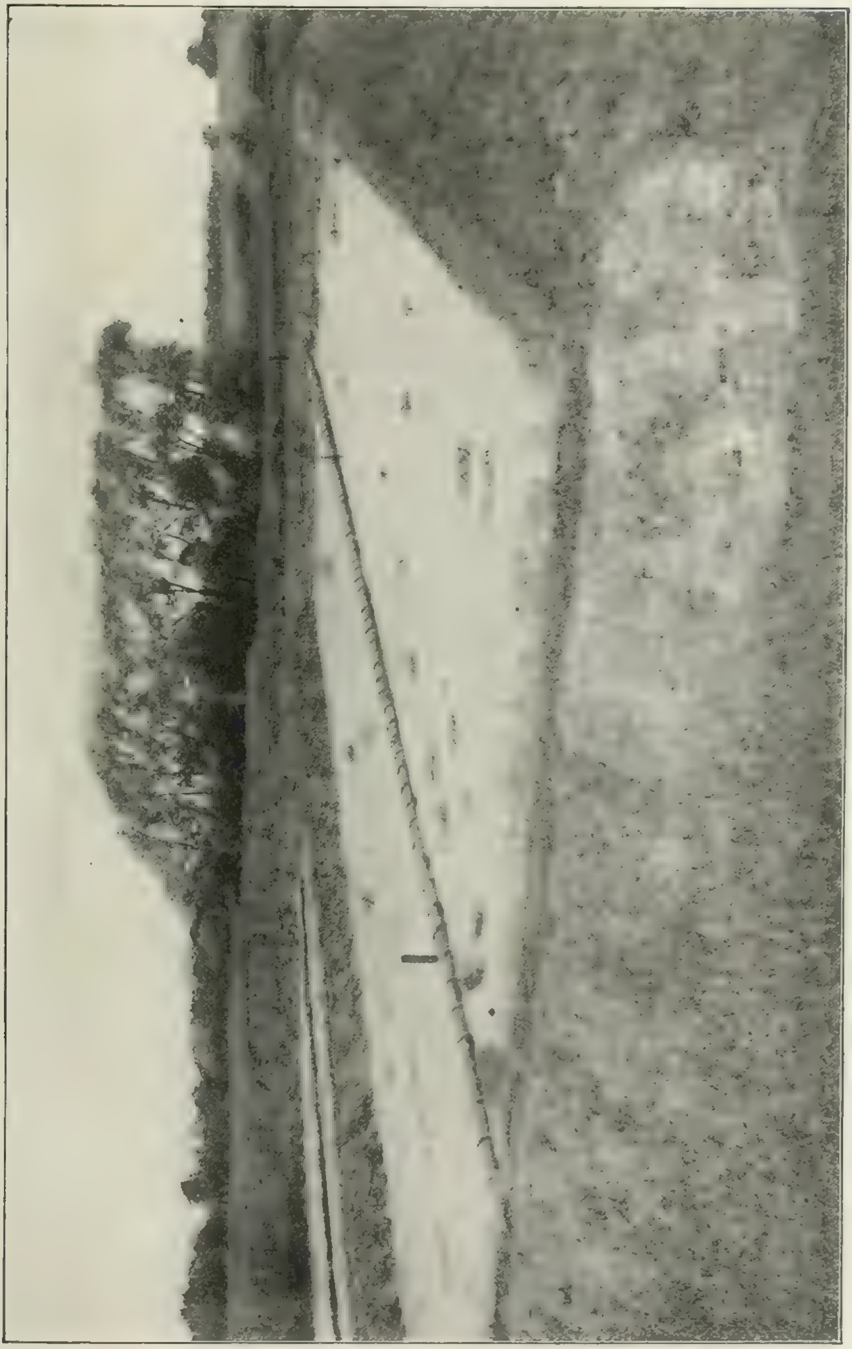


Fig. 49. View of Completed Sewage-Disposal Plant at Ames, Iowa, Consisting of a Septic Tank and Two "Intermittent" Sand Filters.

need not be intermittent as in the case of sand filters. However, the germs do not have time and opportunity to work so thoroughly upon the organic matter as in sand filters.

Efficiency of Sprinkling Filters. This is not nearly so high as for sand filters. Fine, black particles of partially purified organic matter often cloud the effluent to such an extent that settling tanks must be provided for clarification.

Sprinkling filters are suited best to large cities, and to cases where the highest efficiency of purification is not essential.

124. Maintenance of Sewage-Disposal Plants. Sewage-disposal plants, like other forms of apparatus, will not run themselves. For large cities, where men must be constantly employed to care for the large plants, little trouble is experienced in securing proper care; but for small cities, sewage-disposal plants are often almost entirely neglected.

Fig. 50. Iowa State College (Ames, Iowa) Sewage Filters in Winter.

Every sewage-disposal plant should be visited at least once a day by an intelligent man, who should make sure at every visit that everything is operating properly, and who should remedy any trouble found.

Care of Tanks. Septic tanks require cleaning out about once a year. After the sludge is thoroughly dried, it should be hauled away and ploughed under for fertilizer. Besides this, the only care needed is to make sure that no passages are stopped up, that valves are arranged properly, and that siphons or other automatic apparatus work properly.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for Civil Service Examinations. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING

PART I

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1. Under what conditions is a spring of water available for house supply?

2. What methods are adopted of supplementing municipal service in case of insufficient pressure?

3. What are the essential requirements of a good laundry tray?

4. What do you consider the poorest types of water-closets?

5. What are the general methods of supplying buildings with water?

6. How far should the bottom of a cistern be below the cylinder of an ordinary house suction pump?

7. How is *siphonic eduction* effected in the case of range closets? Illustrate by diagram.

8. Describe the part played by lead in modern plumbing.

9. What is a *pneumatic siphon* closet? Give diagram.

10. How can an open-trough range closet be satisfactorily ventilated?

11. How can supply to tanks be automatically regulated?

12. When is a hydraulic ram available for house supply?

13. Describe the various kinds of bathtub supply and waste fittings.

14. What are the advantages or disadvantages of the *combined hopper and trap* and the *wash-out* types of closets? Illustrate by free-hand sketches.

15. Classify bathtubs (1) according to material; (2) according to shape. Illustrate the shapes by freehand sketches. Discuss the relative merits of the different classes of bathtubs.

16. What size of pipe will be needed to discharge 150 gallons a

minute, at a distance of 100 feet under a pressure head of 40 feet? (Use the tables.)

17. How is flushing of urinals effected?

18. What is a *hydraulic ram?* Illustrate by diagram.

19. Describe the different types of lavatories.

20. Under what conditions will the house supply of water be in danger of contamination from the water-closet? How can the danger be obviated?

21. What difficulties are inherent in the use of wooden tanks for outside storage of cold water?

22. Describe the different types of drinking fountains, and their uses.

23. What are the objections to the range type of water-closet? What conditions are absolutely essential to their satisfactory working?

24. Describe the process of *sweating-in* the lining of a lead-lined tank.

25. What is the cause of "sweating" on tanks and piping? How can it be prevented?

26. Discuss the relative merits of the different materials of which water-closet bowls are made.

27. What part does friction play in determining details of pipe and fixture installation?

28. What is meant by a *jet-siphon* closet?

29. Describe the different types of urinals.

30. What different kinds of tanks are made for cold-water storage indoors?

31. Describe, with diagrams, the different methods of tank arrangement in water-closets.

32. How are the effects of grease in sink water avoided? In answering, refer briefly to the different kinds of sinks.

33. What head will be required for the discharge of 150 gallons a minute through a 2-inch pipe 500 feet long? (Use the tables.)

34. Name and describe the parts of a complete shower-bath fixture.

35. Give a definition of *Plumbing* and of *Sanitary Science.*

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING.

PART II.

1. Describe the essential features of a stove or range connection of a reservoir.

2. Explain the principle of the Bunsen burner. What application does it have in connection with lighting by gas?

3. How many square feet of heating surface will be needed in a submerged brass coil filled with steam at 7 pounds' pressure, to raise the temperature of 125 gallons of water per hour from 40 degrees to 200 degrees?

4. What is the cause of rumbling in a reservoir?

5. What is the object of the siphon hole in the delivery pipe in a reservoir?

6. Describe the different classes of filters?

7. Draw a diagram showing connections of hot-water reservoir (1) to a single water-back; (2) to two water-backs on different floors.

8. Explain the function of the air-chamber in a force pump.

9. A house usually settles after being built. If rigid iron service pipes are used, how can the effects of settling be avoided?

10. How are service pipes protected from frost?

11. How many square feet of grate surface will be needed to raise 150 gallons of water per hour from 45 degrees to one of 160 degrees?

12. What rules should be observed in making bends in pipes?

13. What are the salient features of the direct system of supply?

14. Explain the working of a common suction pump. Illustrate by diagram.

15. Name and describe five kinds of gas burners for lighting purposes.

16. When is a lift pump necessary? How does it differ from an ordinary suction pump?

17. In case of temporary stoppage of supply, what precautions should be taken?

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING.

PART III.

1. Describe two types of mechanical-seal traps.

2. Draw rough sketches showing how ventilating loop can be secured (1) when crown vent stack and waste stack stand close together; (2) when these stacks are a considerable distance apart; (3) when neither stack stands near the fixture.

3. Under what conditions would you recommend the use of anti-siphon traps in solving the problem of ventilation?

4. What is meant by the "loop" plan in installation of waste and vent stacks?

5. How are joints made between wrought-iron and cast-iron soil-pipe?

6. Explain the principle of the anti-siphon trap.

7. What considerations determine the size of soil and waste pipes? What would you consider proper sizes for a single dwelling with two closets (1 in basement and 1 on second floor), and with 1 bath, 1 sink, 1 lavatory, and 2 laundry trays?

8. When stacks lead through roof to open air, how is closure of their ends by hoar frost prevented?

9. When fixtures are scattered, how can the necessity for separate stacks be avoided?

10. Under what general heads are traps classified? Illustrate by diagrams (1) A running trap; (2) "S" trap; (3) "P" trap; (4) "$\frac{3}{4}$-S" trap; (5) Bag trap; (6) "Pot" trap.

11. What is meant by local ventilation? Explain by diagram.

12. How may traps lose their seals?

13. How can danger of puffing of soil air from fresh-air inlet be avoided? Give sketch.

REVIEW QUESTIONS

ON THE SUBJECT OF

SEWERS AND DRAINS

PART I

1. Explain what is meant by the *separate* system of sewerage, and name its advantages and disadvantages as compared with the *combined* system.

2. Name the different materials used for sewers, and state the conditions to which each kind of material is adapted.

3. What is a *subdrain*, and when and why should subdrains be used?

4. What should be the minimum size of separate sanitary sewers, and why? Of storm sewers, and why?

5. Why is the egg shape of sewer sometimes used? For what kind of sewers is it advantageous?

6. What nations of antiquity built the first known sewers? When did the scientific design and construction of sewers become general?

7. Give the principal objections to the use of cesspools.

8. What difficulties are encountered in designing and constructing the junctions of large sewers, and what designs are generally adopted for junction chambers?

9. What are the general facts as to the fluctuations in the flow of sanitary sewage at different hours of the day and night?

10. How would you determine the probable flow of sanitary sewage per capita per day, for any particular sewer system? Between what limits would the per capita per day flow probably lie in different systems?

11. How large capacities should the different kinds of separate sanitary sewers have as compared with the average flow of sewage in them?

REVIEW QUESTIONS

ON THE SUBJECT OF

SEWERS AND DRAINS

PART II

1. At 15 cents per cubic yard, what will be the cost of a drainage ditch 1 mile long, 6 feet average depth, and 20 feet average width?

2. What is a *trap*, what are the purposes of traps, and where should they be used? What kind of traps are best?

3. What size and kind of pipe should be used for house sewers, and at what grades should they be laid?

4. What average width of drainage ditch, carrying 5 feet depth of water, will be required to take the drainage of 50,000 acres of land, the grade being 5.3 feet per mile?

5. Estimate the cost, complete, under average conditions, of a 3-ring circular brick sewer, 9 feet in diameter, the average depth to the invert being 16 feet, and the length being 4,900 feet, with 12 manholes.

6. Explain the proper arrangement for the ventilation of a system of plumbing. Why is it necessary to connect the high point of each trap on the sewer side to the main ventilation pipe?

7. State in your own language the principal advantages of tile land drains; of open-ditch drains. Compare tile drains and open ditches for draining land.

8. What size of sewer subdrain, laid to a 0.35 per cent grade, will be required for outlet for 26,000 feet of tributary subdrains, under ordinary soil and ground-water conditions?

9. What is a *soil pipe;* of what size and material should it be made, and how high should it be extended?

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